Final Design Report

Name of institution: Brick School Of Architecture

Team name: NEST

Competition division:
On-site construction worker housing

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1.Executive Summary

The team started with formulating a consolidated vision to create a net-zero design for construction workers. Each member was assigned with specific role according to their skill sets in order to master each of their respective field. In addition to this, to ensure all topics function in unison, regular deliberations were carried out since the all the fields were interdependent.

After brainstorming on facts related to construction worker housing, the team identified critical aspects to cater the issues faced by on site construction workers. Based up on a detailed research on different locations and conditions, a problem statement was prepared and a design brief was made.

Once these issues were identified, an analysis was carried out by visiting different scales of onsite workers camp. A thorough knowledge of the existing scenario, based on different heads including planning, services, affordability, lifestyle, sustainability and reusability was gathered. Further, considering the conditions for each of the site, it's scale, typology, detailed analysis was done to in turn understand the pros and cons for each project. This understanding helped the team look forward with the concept of net-zero construction worker housing.

The Metro Rail project is undertaken by the government of India and is being implemented in different cities across the nation. With the help of commutable and cutting edge technology with respect to net-zero design, our project would make a mark in the Metro Rail project by having simple modifications that can represent themselves anywhere in the country. Pune Metro Project is one of the predominant infrastructural development taking place in heart of Maharashtra. Thousands of workers, specialised in various fields of work are been engaged with the project. Such huge number of workers on site brings its own set of challenges with it. The Multi Modal Transit Hub at Swargate is one of the largest infrastructural development happening in the city which would connect the metro to other modes of transport such as MSRTC, PMPML, taxis and rickshaws, etc and would encourage last mile connectivity. A net-zero worker housing for such an intensive project would make an impact on such projects under MAHA Metro, as well as various private construction projects.

With a goal to achieve zero dependency on any external source, the team came up with different strategies such as on site renewable energy generation which helped reducing the Energy Performance Index from 29 kWh/Sq. m/ Year to 24.18 kWh/Sq. m/ Year. The solar PV panels generate a total energy of 10,950 kWh/Year and the payback period for the same turned out to be 30 months. Apart from roofing shingles, the sullege from the toilets is been effectively converted into energy by the use of a mini power plant. The excess amount of energy that is generated will be supplied to the ongoing metro project. The rain water will be collected into percolation pits by the use of root zone technology and will be then reused for the purpose of washing. The efficient use of bio digester toilets reduced the daily water consumption by approximately 30%. Innovative materials such as eucalyptus particle boards reduced the heat gain and provided efficiency in terms of affordability. Excavated debris from can be reused in the plinth work thus ensuring effective reuse of materials. Easy availability of these materials increased the market potential of the project.

The design evolves considering the concept and evidence-based impression to facilitate the need of on-site construction worker housing typology. The planning of the modular structure is been thoroughly tested through simulations and is made sure that it facilitates the efficient use of natural resources. The design needed to break the ordinary conceptions about worker housing colonies and thus provide a healthy lifestyle for them. The form evolves from a grid of size 3m x 3m that change the dynamics of the structure still holding its essence. Architectural design elements such as courtyards, buffer zones, open areas, shaded and semi open spaces enhance the overall character of the project.

The ultimate aim for the team stands to execute a construction worker housing which is modular in its style contributing to the ease of assembly, that provides one with a healthy lifestyle along with suitable thermal comfort which in turn reduces the initial capital investment and provides affordable solutions for the typology.

2.1 Team Name : Nest

2.2 Institutions Participating : SMEF's Brick School of Architecture, Pune
PCET'S Pimpri Chinchwad College Of Engineering, Pune.

2.3 Division : On-site construction worker housing

2.4 Team Members

Fig 2.4.1 - Team Members

2.5 Faculty Lead : Ar. Divya Mallavarapu

Ar. Divya has a mixed bag of experiences of more than 9 years. Her experience ranges from Environmental Architecture to Project Management. She has worked in US, New Zealand along with India. She loves to interact and shape up young minds towards sensitive, sensible and sustainable designs. She believes that architecture needs to be an essence of the environment and drives this thought through her teaching as well.

2.6.1 Faculty Advisor : Dr. Poorva Keskar

Dr. Poorva Keskar is an architect, environment designer, quality manager, educator and author of numerous articles on the practice of environment design and environment management. She is the Director at VK:e environmental, a consultancy firm . Her practice has won the HUDCO national award for outstanding green rated office building and the AESA award for her LEED project for skf bearings in the year 2015.

2.6.2 Faculty Advisor : Ar. Vinita Lulla

Ar. Vinita has a flair for sustainable architecture, chases creativity minutely and adds aesthetics in everything she perceives. Having completed her Master's in Environmental Architecture and being a passionate designer, helps her create a niche with a unique combination of art, design, and technical expertise. She is ecstatic at the opportunities to bring more sustainably designed buildings and a built environment, which is the need of the time and a way forward.

2.7 About Our Institute:

SMEF's Brick School of Architecture formed in 2013 by Satish Misal Educational Foundation aims to reach a diverse population of students and spread the knowledge of design amongst aspiring inventors.
Link: https: //brick.edu.in/Bricks

2.8 Design Approach:

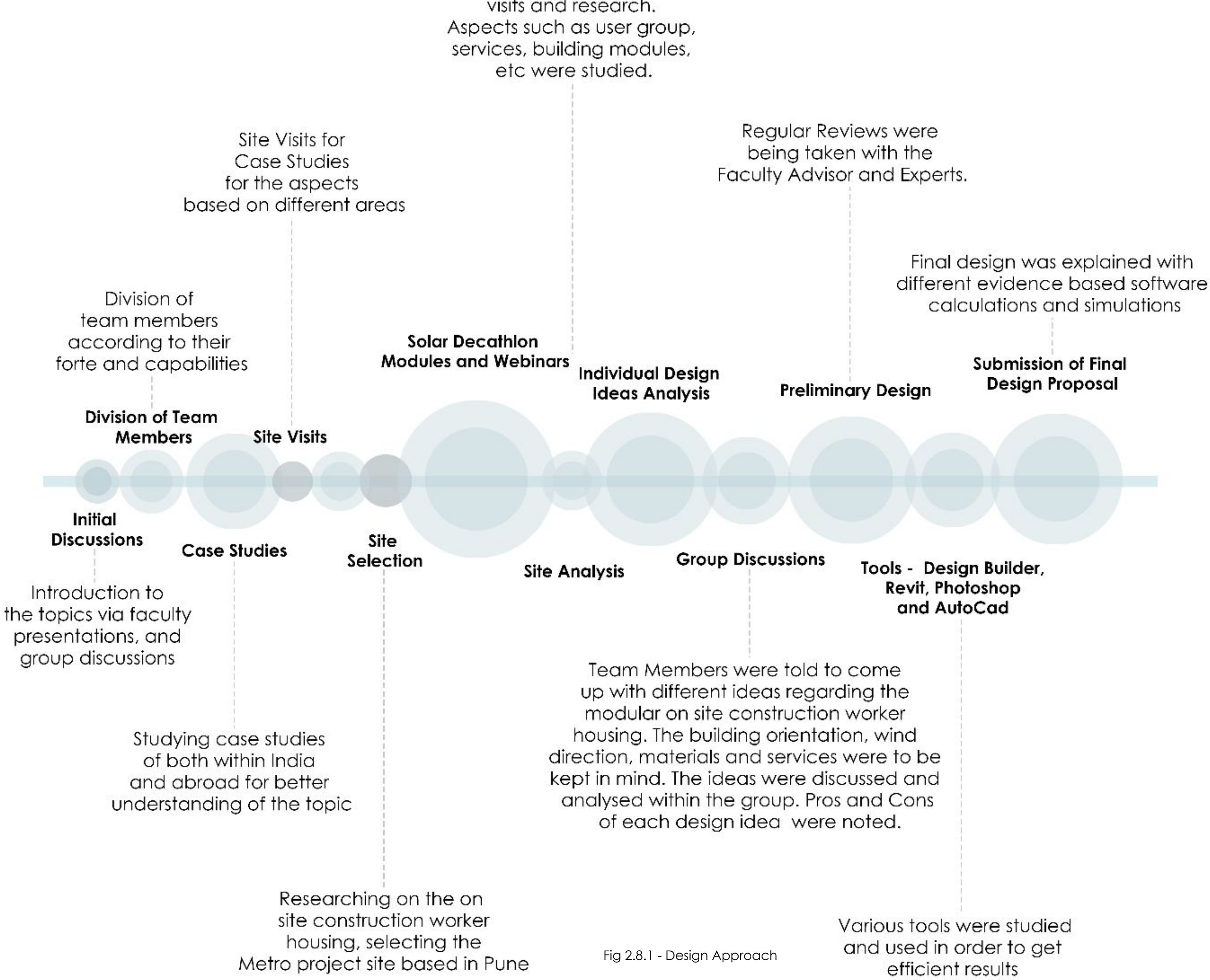


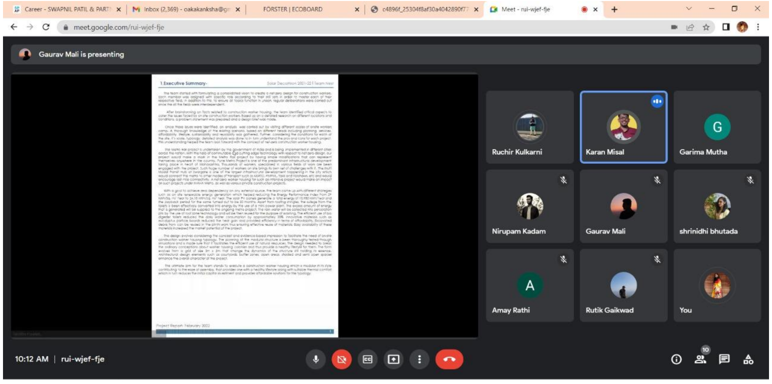
Fig 2.8.1 - Design Approach

2.9 Challenges Faced:

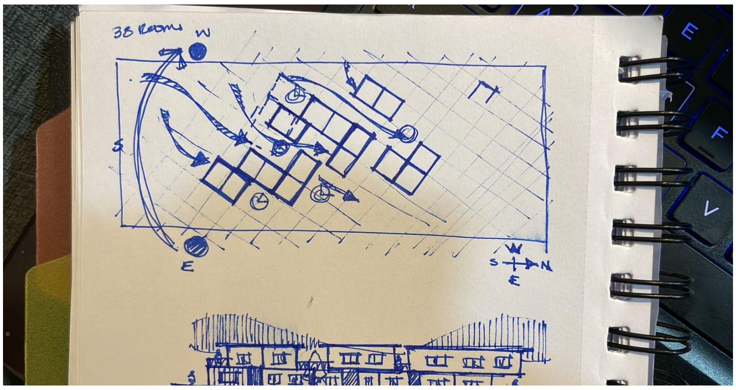
1. As Pune is a fastest growing city, thus infrastructure is increasing rapidly. Hence this growing construction requirement of city allows many construction labourers employment and living.
2. Currently condition of these labour camps needs to improved on a large scale, but as this problem is prominent yet scattered, one universal solution is very difficult to propose considering various aspects like climate,affordability and reusability.
3. For large scale projects where the construction is in phases, the location of labour camps changes. Hence, structures to be designed are supposed to be easy to work with, dismantable and transportable. These technically aspects needs certain skilled abilities to erect the camps.

2.10 Tools Used:

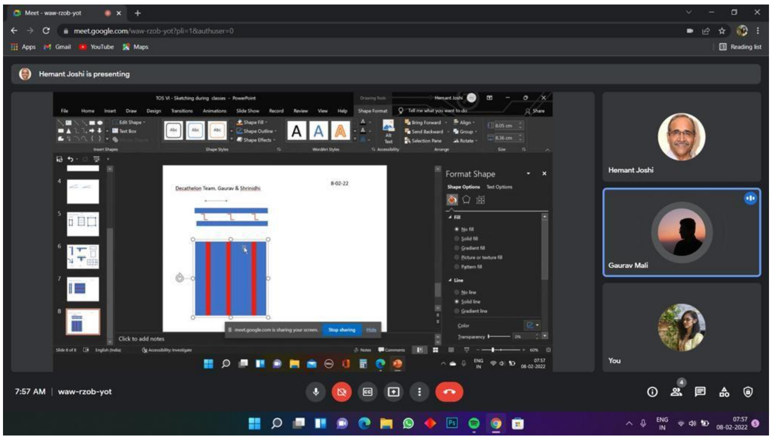
2.11 Design Documentation process:



Online group work

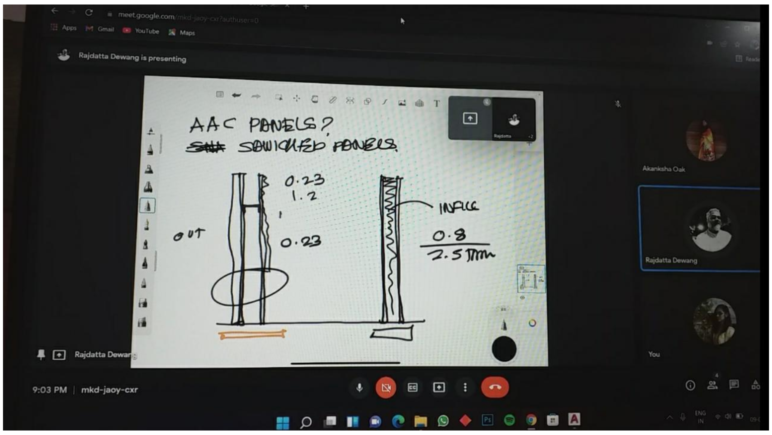


Design brainstorming sessions



Structural guidance by faculty

Preliminary design



Design discussions with faculty

Preliminary simulations

Live site visit

Discussion with partners

3. Project Summary-

3.1 Project name: Nest

3.2 Project Partner : Maharashtra Metro Rail Corporation Limited (MAHA-METRO)

महा मेट्रो

PUNE METRO

MAHA-METRO, a Special Purpose Vehicle (SPV), is a 50:50 jointly owned company of the Government of India and the Government of Maharashtra. The existing Nagpur Metro Rail Corporation Limited (NMRCL) which would be reconstituted into Maharashtra Metro Rail Corporation Limited (MAHA-METRO) for implementation of all metro projects including Pune Metro Rail Project Phase-1 in the State of Maharashtra outside Mumbai Metropolitan Region for the smooth implementation, execution, and operations.

The project is covered under the legal framework of the Metro Railways (Construction of Works) Act, 1978; the Metro Railways (Operation and Maintenance) Act, 2002; and the Railways Act, 1989, as amended from time to time.Swargate multimodal hub, first of its kind in India with the integration of Metro Rail, City bus, and long-distance bus services. Integrated Multimodal hub on top of Swargate underground Metro station for seamless movement of passengers. Hub building is 105 m tall with 6 floors over ground and 5 levels underground. The project has a built-up area of 6,04,000 Sq.m.

Project partner representatives

Mr. Atul Gadgil - Director (Works), MAHA Metro, Pune
Mr. Rajesh Jain - Additional Chief Project Manager, MAHA Metro, Pune
Mr. Madhusudanan VJ, Manager, MAHA Metro, Pune

3.3 Project Description

Project Typology	-On-site Construction Worker housing
Location	- Near Jedhe Chowk, Swargate, Pune- 411037
No. of Workers on site	-150 nos.
Occupancy Hours	-10-12 hrs- 7.00pm to 8.00am
Climatic Conditions	-Composite Climate (After comparing statistics from ECBC 2017)
Plot Area	- 3513.36 sq.m
Total Built up Area	- 631.73 sq.m
No. of Floors	- G+1 structure

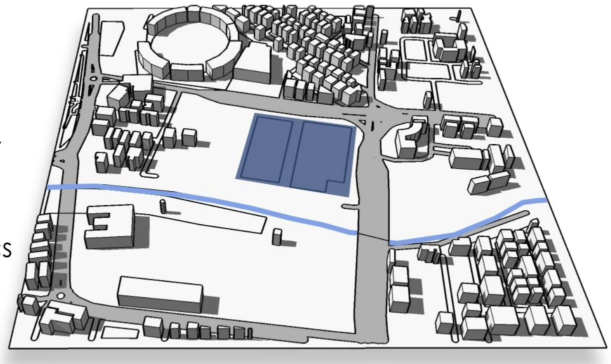
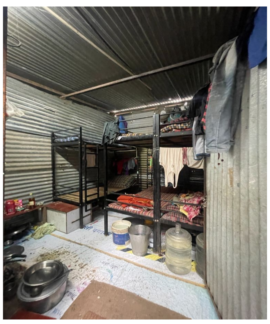


Fig 3.3.1 - Site Context

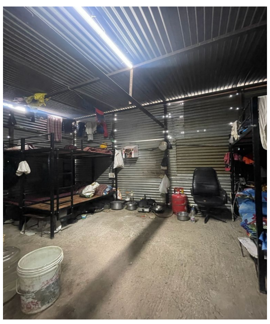
3.4 Current scenario

The construction worker housing would accommodate 150 workers near site. These workers mainly travel from Bihar, Bengal, Jharkhand, and other parts of Uttar Pradesh. These construction workers work for around 8 to 10 hours per day. They have been divided into different categories based upon the item of work such as steelworks, excavation works, carpenters, drivers and crane operators, masons, etc. Out of these, the crane operators and drivers, R.C.C steelworkers are accommodated near the site whereas other 300-400 workers are accommodated at a distance of about 1.5km from the site. These workers are provided with basic facilities like rooms with six to eight workers staying in one room, electricity from MSEB, drinking water facility from PMC, timely sanitation done on every alternate day, a 24 hr nurse along with first aid facility on the site, a kitchen for them, fire fighting services and toilets on site. The garbage management system is managed by the Municipal Corporation. The wastewater is collected in a septic tank and then is taken away by the municipal corporation vehicles. The project is to be completed by 2024.

Storage yard



View of rooms



View of rooms

Exterior view

Exterior view

Fig 3.4.1 - Current Scenarios

3.5 Why Metro?

The Metro Rail project has been undertaken by the government of India and is being implemented in different cities across the nation. With commutable and cutting edge technology with respect to net-zero design, our project, on-site construction worker housing, would make a mark in the Metro Rail project by having simple modifications that can represent themselves anywhere in the country.

3.6 Why Pune?

Pune Metro Project is one of the predominant infrastructure development happening in the heart of Maharashtra. Thousands of workers, specialised in various fields of work are been engaged with the project. Such huge number of workers on site brings its own set of challenges with it.

The Multi Modal Transit Hub at Swargate is a large infrastructural development happening in the city which would connect the metro to other modes of transport such as MSRTC, PMPML, taxis and rickshaws, etc and would boost last mile connectivity.A net-zero worker housing for such an intensive project would make an impact on more such projects under MAHA Metro, as well as various private construction projects .

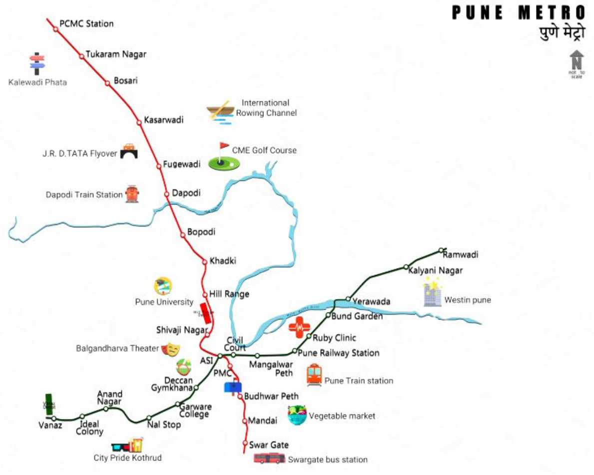


Fig 3.6.1 - Route Map of Pune Metro

3.7 Ongoing Major Metro Works in Pune

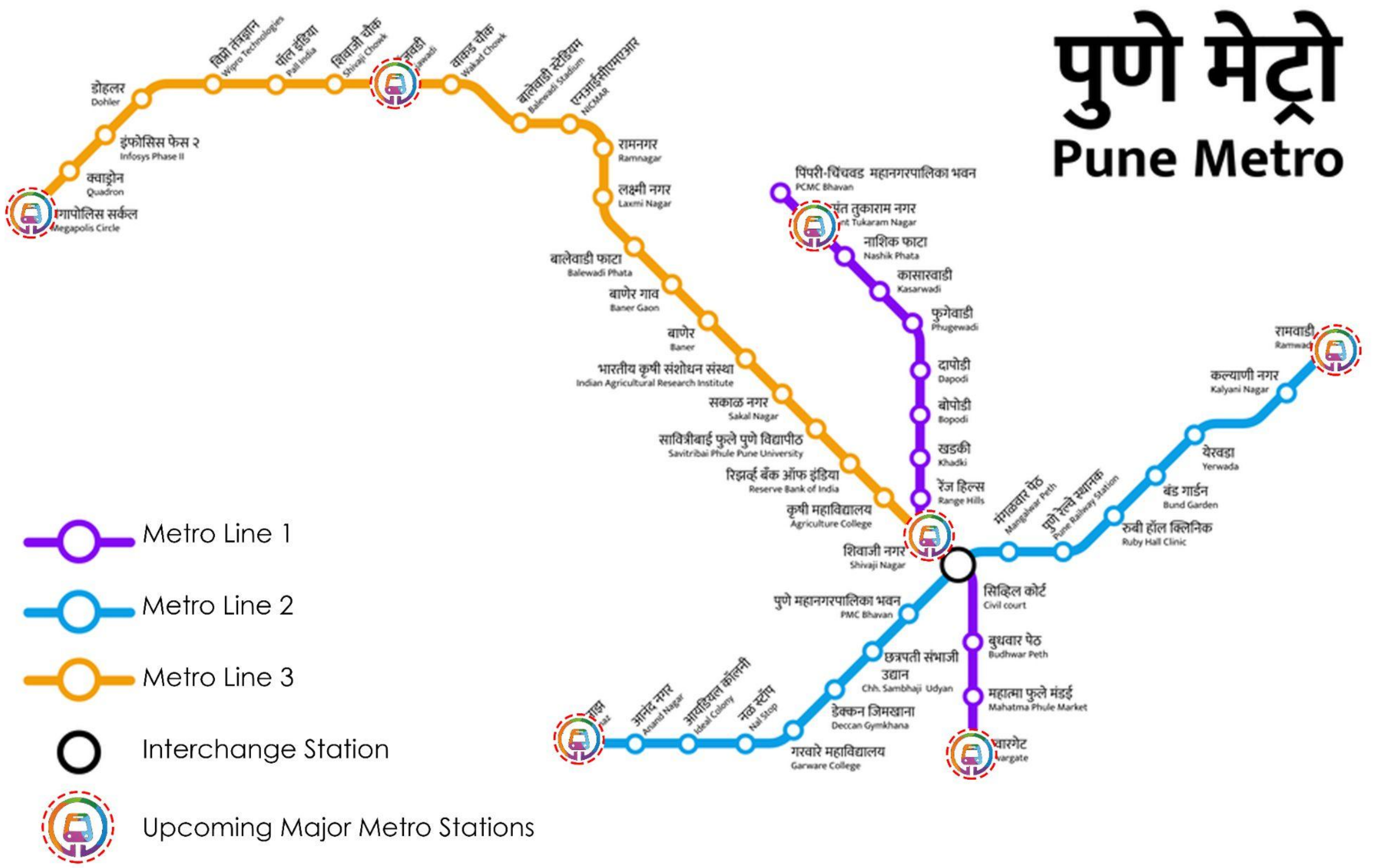


Fig 3.8.1 - Ongoing Metro works in Pune

3.8 Summary of Cost Estimate

Project Summary						
S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)		Proposed Design Estimate	
			Amount (Rs Millions)	%	Amount (Rs Millions)	%
1	Land	Cost of land purchased or leased by the Project Partner	0.00	0.0%	0.00	0.0%
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	1.13	44.8%	1.11	44.0%
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	0.72	28.6%	0.60	23.8%
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	0.09	3.6%	0.09	3.6%
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	0.26	10.3%	0.26	10.3%
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	0.08	3.2%	0.08	3.2%
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	0.012	5.0%	0.012	5.0%
	TOTAL HARD COST		**2.52**	**100.0%**	**2.05**	**100.0%**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	-	0.0%	-	0.0%
9	Consultants	Consultant fees on a typical Project	-	0.0%	-	0.0%
10	Interest During Construction	Interest paid on loans related to the project during construction	-	0.0%	-	0.0%
	TOTAL SOFT COST		**0.00**	**0.0%**	**0.00**	**0.0%**
	TOTAL PROJECT COST		**2.52**	**100.0%**	**2.05**	**81.3%**
	Total Project Cost per Sq.m of Built-up Area		**0.00398**		**0.00324**	

4. Goals

RESILIENCE

We have made the structure capable to withstand natural calamities and environmental challenges.

WATER PERFORMANCE

We have reduced the overall water demand by 30% which enhances the overall functioning of the structure.

ENERGY PERFORMANCE

We achieved an EPI of 24.18 kWhr/sq.m per year, which is less then 27.83 kWhr/sq.m per year observed in the base case scenario.

ENGINEERING AND OPERATION

The Nest minimizes energy consumption and wastage of material during construction and operation.

ARCHITECTURAL DESIGN

The project focuses on executing a construction worker housing which is modular in its style contributing to the ease of assembly, that provides one with a healthy lifestyle.

SCALABILITY AND MARKET POTENTIAL

Introduction of the notion of reusable habitation for projects by setting an example in terms of affordability.

AFFORDABILITY

The proposal reduces the total construction cost by 30% and studies the cost impact analysis.

INNOVATION

The project has innovative use of material to achieve a net-zero design.

HEALTH AND WELL BEING

Project ensures indoor environmental quality (air quality, visual, thermal and acoustical comfort)

CLIMATE RESPONSIVE

The project nullifies the structure's reliance on artificial energy and to improve the wellbeing of labour camps by making it sensitive to its surroundings.

COMMUNICATION

The proposal scales up the necessity of refurbishing construction worker housing and reaching out to clients, users and visitors thus amplifying the project idea.

Design Case		Base Case	
Eucalyptus Particle Boards		GI Sheets	
U- Value (W/m2-K)	0.36	U- Value (W/m2-K)	1.2
Density (Kg/m3)	760	Density	1600
Width (mm)	25	Width (mm)	6
Resistance	Fire Resistant	Resistance	Thermal Resistance
Roof Slab		Roof Slab	
U- Value (W/m2-K)	0.136	U- Value (W/m2-K)	1.2
Density (Kg/m3)	760	Density (Kg/m3)	1600
Configuration	150mm thk. panel supported with M.S. angle sections	Configuration	6mm thk. GI roofing sheets
Appearance	White	Appearance	Silver
Manufacturer	Eurowoods	Manufacturer	Jindal
Glazing		Glazing	
Thickness	4mm	Thickness	4mm
SHGC	0.58	SHGC	0.84
Light Transmission	87%	Light Transmission	88%
U- Value (W/m2-K)	0.16	U- Value (W/m2-K)	5.9
Company	Longlasst	Company	National Glass
Brand	Saint Gobain	Brand	Asahi Glass
Colour Shade	Transparent	Colour Shade	Transparent

Table - 5.1 Building Envelope

Renewable Energy Generation	
Total Energy Generation Per Day	19.952 kWh
System Type	Grid Unconnected
Solar PV Generation Capacity	5763.91 W
Brand	Kirloskar
Model Type	250W
Dimensions	1650mm x 992mm x 40mm
Weight	17 kg

Table - 5.2 Renewable Energy Generation

Solar Water Heater	
Water Heater Type	Solar
Quantity	
Capacity	400LPD
Brand	Redren
Model	Novice
No. of Tubes	28

Table - 5.4 Solar Water Heater

Lighting Specifications								
Spaces	Area (Sq.m)	No. of Luminaries	No.of Rooms	Power (W)	Total Power (W)	Product Description	Resulting and Target Illuminance	LPD (W/Sq.m)
Security Cabin	9.00	2	1	8.5	153	PHILIPS 8W B22 LED Cool Day Light Bulb	300 to 2000 lux	17
Nurse Room	15	4	1	10	600	wipro 10W B22 LED Cool Day White Bulb	301 to 2000 lux	40
Electrical Room	30	8	1	8.5	2040	PHILIPS 8W B22 LED Cool Day Light Bulb	302 to 2000 lux	68
Dormitories	9	2	32	10	5760	wipro 10W B22 LED Cool Day White Bulb	303 to 2000 lux	640
Kitchen	61	19	1	10	11590	wipro 10W B22 LED Cool Day White Bulb	304 to 2000 lux	190
Store Room	20.4	4	1	10	816	wipro 10W B22 LED Cool Day White Bulb	305 to 2000 lux	40
Dining Area	80	24	1	12	23040	wipro 12W LED White Bulb, (NE1201)	306 to 2000 lux	288
Toilets	1.69	1	48	5	405.6	PHILIPS 8W B22 LED Cool Day Light Bulb	307 to 2000 lux	240

Table - 5.5 Lighting Specifications

Ceiling Fans								
Spaces	No. of Fans	Watts	Total Wattage	Area	Power Density (W/Sq.m)	RPM	Blades	Brand
Security Cabin	1	35	35	9	3.89	365	3	Sinox
Kitchen	3	35	105	61	1.72	365	3	Sinox
Dining	6	35	210	80	2.63	365	3	Sinox
Dormitories	32	35	1120	9	124.44	365	3	Sinox
Nurse Room	1	35	35	15	2.33	365	3	Sinox

Table - 5.6 Ceiling Fans

Miscellaneous						
Type	Power	Nos.	Total Wattage	Power Density	Brand	Description
Socket 1	12	32	384	1418	Exquisite Export International	Exquisite Export International 3+1 Universal 6/13 amp Multi Socket Extension Board Indicator model with 1.5mm 3 Core ISI Copper Wire Cable
Socket 2	12	32	384		Exquisite Export International	Exquisite Export International 3+1 Universal 6/13 amp Multi Socket Extension Board Indicator model with 1.5mm 3 Core ISI Copper Wire Cable
Fridge	150	1	150		Godrej	Godrej 190 L 5 Star Inverter Direct-Cool Single Door Refrigerator
Food Grinder	500	1	500		Phillips	PHILIPS HL7707/00 750W Mixer Grinder

Table - 5.7 Miscellaneous

6.1 Site Analysis

Site area : 3513.36 sq.m

Location: Near Jedhe Chowk,Swargate,Pune-411037

Project info : Swargate multimodal hub is first of its kind in India with the integration of Metro Rail, City bus, and long-distance bus services. There are a total of 150 workers staying near site. These construction workers work for around 8 to 10 hours per day.

Design study : The design process was initiated by pre-design analysis where climatic conditions, best suitable materials and building technologies possible were studied. This study was followed by a volumetric experiments according to the context and space requirements which meet to the primary design stage.The site was designed to achieve Net-zero design using different design strategies and innovative technologies.

Fig 6.1.1 - Site Plan

6.2 Climate Analysis :

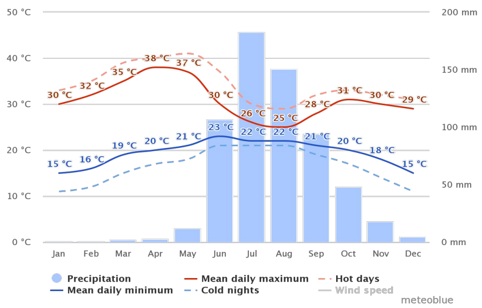


Fig 6.2.1 - Average temperatures and precipitation

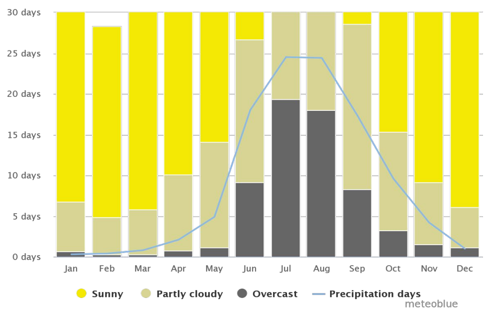


Fig 6.2.2 - Cloudy, sunny and precipitation days

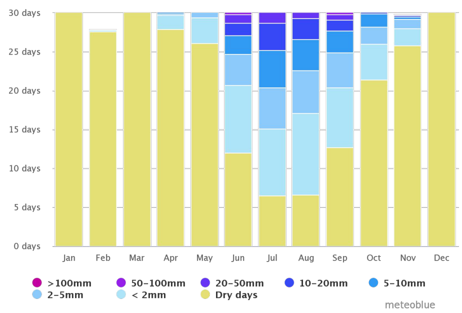


Fig 6.2.3 - Precipitation amount

6.3 Swot Analysis :

strengths

- Government funded project
- Site is located at the prime location of the city
- Ease of transportation
- Availability of Services

weaknesses

- Congestion at access points within the site .
- Located along an important vehicular node ,has noise and air pollution issues .

opportunities

- Maintaining flexible design solutions w.r.t unit design
- Reuse of the grid system
- Site context has a cultural connect of the city and a varied economic class residing in the vicinity

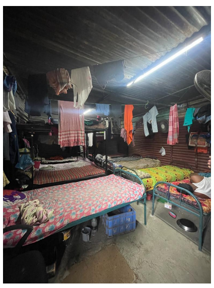
threats

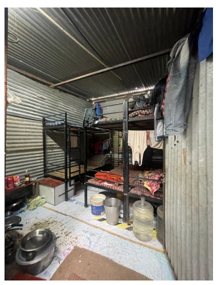
- Water logging on ground during rains
- Water canal adjoining the site may affect the camp during monsoons.

6.4 Site Condition :



A single lane of units lacks interactive spaces and a sense of communal living .Provisions for garbage and utility area is bear minimum and needs to have a better hygienic approach .





The existing site consists of sheds as livable spaces where workers live in claustrophobic and congested units having least natural ventilation and light .

Fig 6.4.1 - Current Scenario

6.5 Design Ideation :

- Our aim is to create a housing for the workers which would not be just a lane of sheds but a community living with well designed and hygienic community spaces .
- The cluster of units has enough central open spaces creating a sense of community living and act as catalysts for enhancement of natural light and ventilation .
- Strategically planning of the units for mutual shading helps the central space to act as a buffer to other blocks.

Space Division :

PUBLIC AREAS	SEMI PRIVATE AREAS	PRIVATE AREAS
Assembly point	Recreational area	Residential area
Garbage yard	General store	Locker rooms
Nurse room	Dinning	Kitchen
Community hall	Store room	Security room
Services		Washrooms
		Bathing

Fig 6.5.1 - Space division

6.6 Site Zoning :

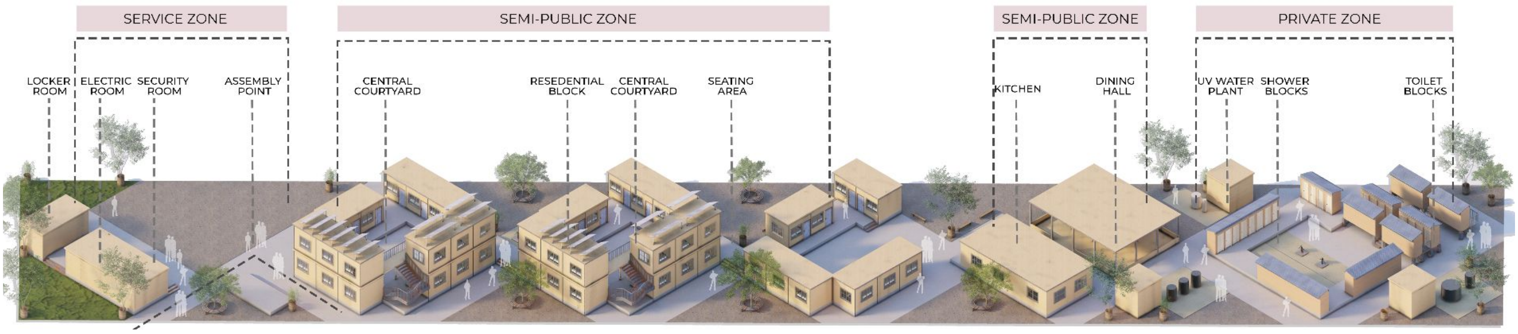
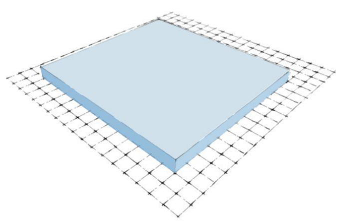
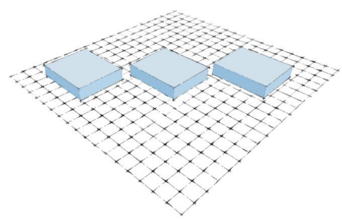


Fig 6.6.1 - Site zoning

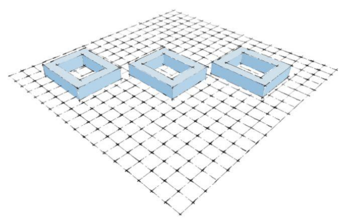
6.7 Design evolution :



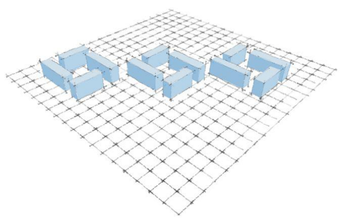
The mass was distributed across the grid considering the site context and volume, keeping the mass as a low rise module.



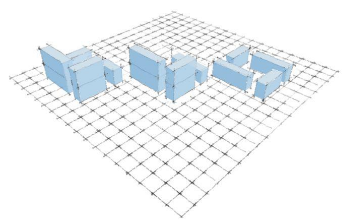
The complete mass is divided into 3 clusters catering the need of open spaces and building orientation at an angle of 45 degree.



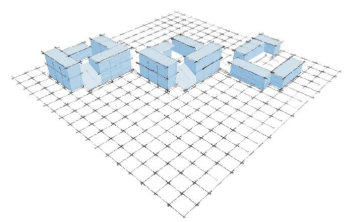
The central mass within the three clusters are carved out to create well ventilated and illuminated courtyards.



The pathways are designed along the grids which connect the courtyards with outside spaces



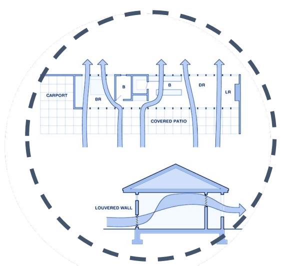
The first floors of two clusters are elevated consideration the sun path and wind flow and achieve mutual shading.



The final design module generated leads to optimum light and ventilation across the site which includes implementation of passive design strategies.

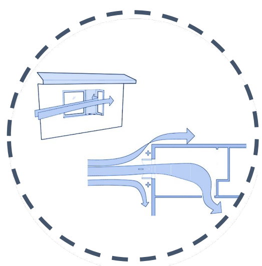
Fig 6.7.1 - Design Evolution

6.8 Passive Design Strategies:

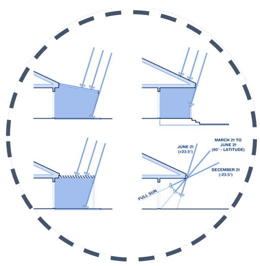


Cross - ventilation for good air circulation

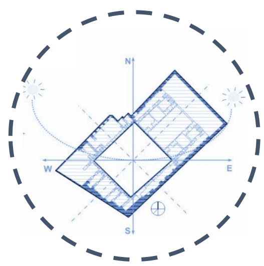
Roof overhangs acts as mutual shading device



Bigger opening for Light and air ventilation



Overhangs designed studying the climate conditions



Building Orientation

Fig 6.8.1 - Passive Design Strategies

6.9 Architectural Design-

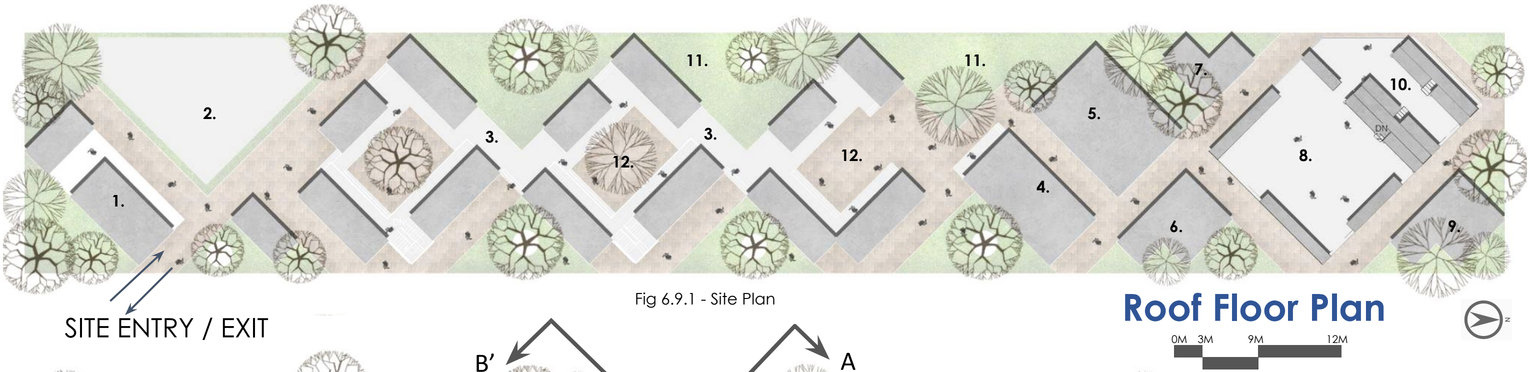


Fig 6.9.1 - Site Plan

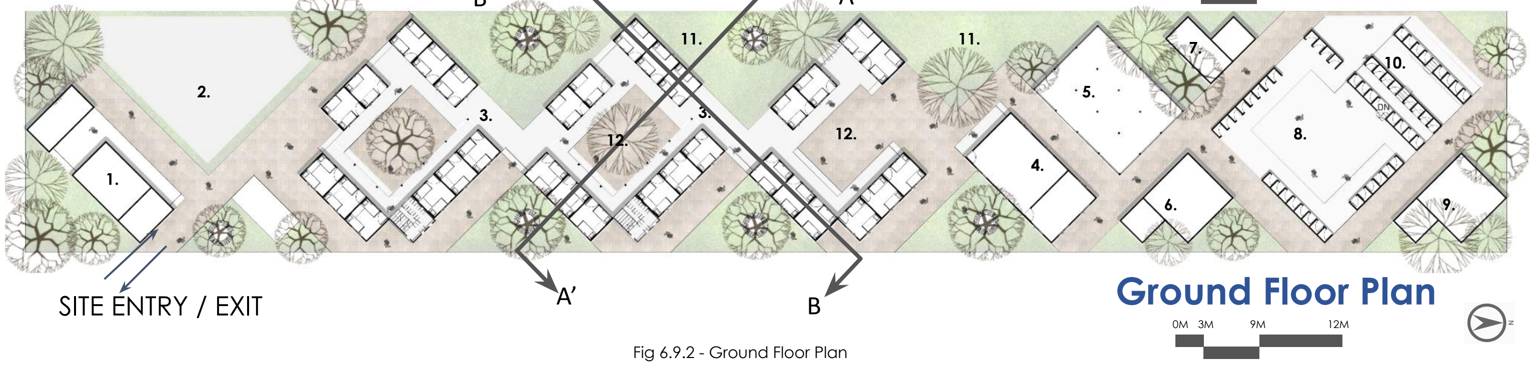


Fig 6.9.2 - Ground Floor Plan

Legend

1. Security room & Services
2. Assembly point
3. Residential Block
4. Kitchen Area
5. Dining hall
6. Water Treatment Plant

1. R.O Filter plant
2. Bathing Area
3. Biogas Plant & Storage
4. Toilet Block
5. Seating Area / Tree Katta
6. Central Courtyard

Space	Area
Security Cabin	8.4 Sq.m
Assembly Point	162 Sq.m
Garbage Collection Yard	8.4 Sq.m
Nurse Room	13 Sq.m
Recreational Area	280 Sq.m
Utility Area/ Washing Area	18 Sq.m
Washrooms (24 Nos)	40 Sq.m
Bathing Area (28 Nos)	40 Sq.m
Community Kitchen (6 Nos)	38.2 Sq.m
Dining Area	104 Sq.m
Residence (Bunk Beds) 38 Rooms	376.2 Sq.m
Store Rooms	18.3 Sq.m
General Store	24.2 Sq.m
Service Area	55 Sq.m

Table - 6.9.1. Design Area Programme

Since,site is elongated rectangle we used this condition to separate out and segregate different spaces into public private and semi private zones. This helped us in organizing residential and service blocks.

During primary design stage, orientation factor was studied as a part to cater the climatic conditions and use it in a way to design the residential block using passive strategies. The site has a composite climate hence the material chosen for walls and roofs, size of the openings, orientation, use of courtyards were the design considerations .

A minimalistic approach is taken while designing and keeping in mind the design concepts like inside-outside, grid planning, symmetry, compact planning etc. The spaces are assembled on the basis of their usability in terms of public, semi-public and private. Different community spaces are proposed for public interaction, community kitchen ,central courtyard, and seating areas that acts as a buffer for other spaces. Aiming towards net-zero, various strategies are used like passive strategies, solar panels, root-zone system, waste management, and rain water harvesting.

Fig 6.9.3 - Section AA'

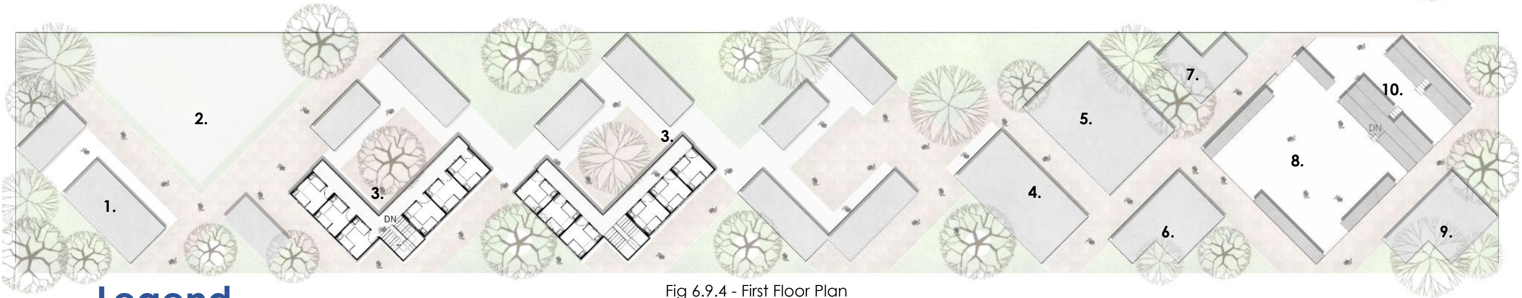


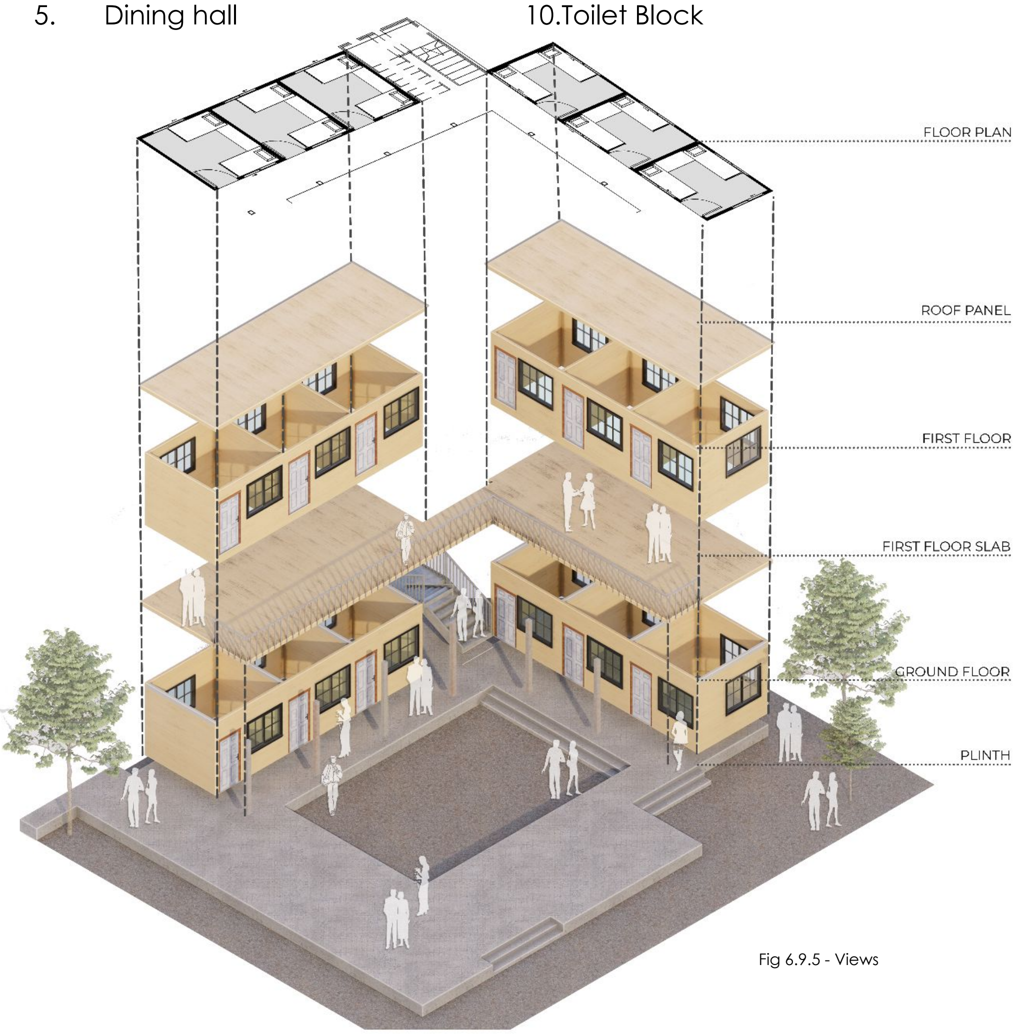
Fig 6.9.4 - First Floor Plan

First Floor Plan

0M 3M 9M 12M

Legend

1. Security room & Services
2. Assembly point
3. Residential Block
4. Kitchen Area
5. Dining hall
6. Water Treatment Plant
7. R.O Filter plant
8. Bathing Area
9. Biogas Plant & Storage
10. Toilet Block



Recreational Area

Entrance Area

Central Courtyard

Fig 6.9.5 - Views

EXPLODED ISOMETRIC VIEW

0M 1.5M 4.5M 9.0M

SECTION BB'

Fig 6.9.6 - Section BB'

6.10 Energy Performance-

The design optimisation is based on the EPI values considered from the benchmark cases provided in the ECBC-R. By trying and testing design objectives with different materials, the most economical section with respect to EPI value, U- value, cost, etc. are selected. This experimentation includes taking results from pre-design simulations and further improving the passive design strategies such as orientation, shading, materials, openings, etc. Once the passive strategies were finalised, the design focused on enhancing the intangible aspects such as thermal comfort, illumination, renewable energy generation, mechanical ventilation, etc. Numerous strategies such as solar PV for net-zero energy generation, waste to energy through biogas plant where organic waste is converted into energy, reuse of waste water have been considered sensitively.

	Area [m2]
Total Building Area	363.08
Net Conditioned Building Area	363.08
Unconditioned Building Area	0

Table 6.10.1 - Area Calculations

6.10.1 Energy Performance Index Calculations-

	Base Case			Design case		
	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	11103.93	**27.83**	**27.83**	8777.6	**24.18**	**24.18**
Net Site Energy	11103.93	**27.83**	**27.83**	8777.6	**24.18**	**24.18**
Total Source Energy	35166.14	35166.14	88.15	27798.66	76.56	76.56
Net Source Energy	35166.14	35166.14	88.15	27798.66	76.56	76.56

Table 6.10.1.1 - Energy Performance index calculations

6.10.2 On-Site Daily Energy Consumption-

Appliances	Power Rating (Watt)	No. of Rooms	Total Power Rating (Watt)	No. of Appliances	No. of Rooms	Use in Hours	Energy Consumption in kWh
Rooms							
LED Bulb	10	32	380	2	32	6	3.84
Mobile Charger	12		456	2		3	2.304
Socket	12		456	2		3	2.304
Fan	35		1330	1		6	6.72
Kitchen And Dining							
Fridge	150	1	150	1	1	8	1.2
Food Grinder	500		500	2		2	2
Socket	12		12	4		2	0.096
LED Bulb	12		12	19		6	1.368
Exhaust Fan	30		30	2		2	0.12
Fan	35		35	3		3	0.315
Toilets							
Exhaust Fan	30	48	1440	1	48	2	2.88
LED Bulb	8		384	1		2	0.768
Store Room							
LED Bulb	8	1	8	1	1	6	0.048
Miscellineous							
Pumps	370	1	370	1	1	2	0.74
Total	773		5563	35	82	38	**24.703**

Table 6.10.2.1 - On-site Daily Energy Consumption

6.10.3 Solar Potential-

The total annual energy consumption of the project is 8777.6 kWh/yr. According to table 6.10.2.1, the energy consumed due to different forms of appliances throughout the housing is 24.04 kWh, whereas the energy generated through solar panels is 30.41 kWh. Hence, the total annual energy generation by Solar PV's is 10950 kWh/yr. Therefore, after deducting the energy consumption from the generation, the total energy left is 2,172.4 kWh/yr. The project thus achieves net positive benchmark.

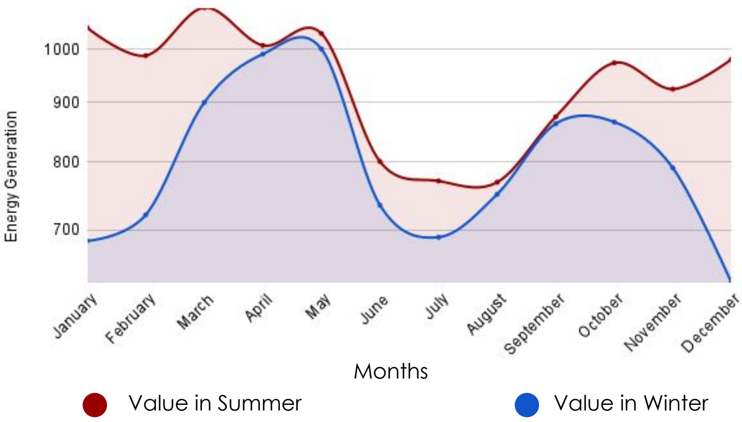


Fig 6.10.3.1 Solar Energy Generation per month

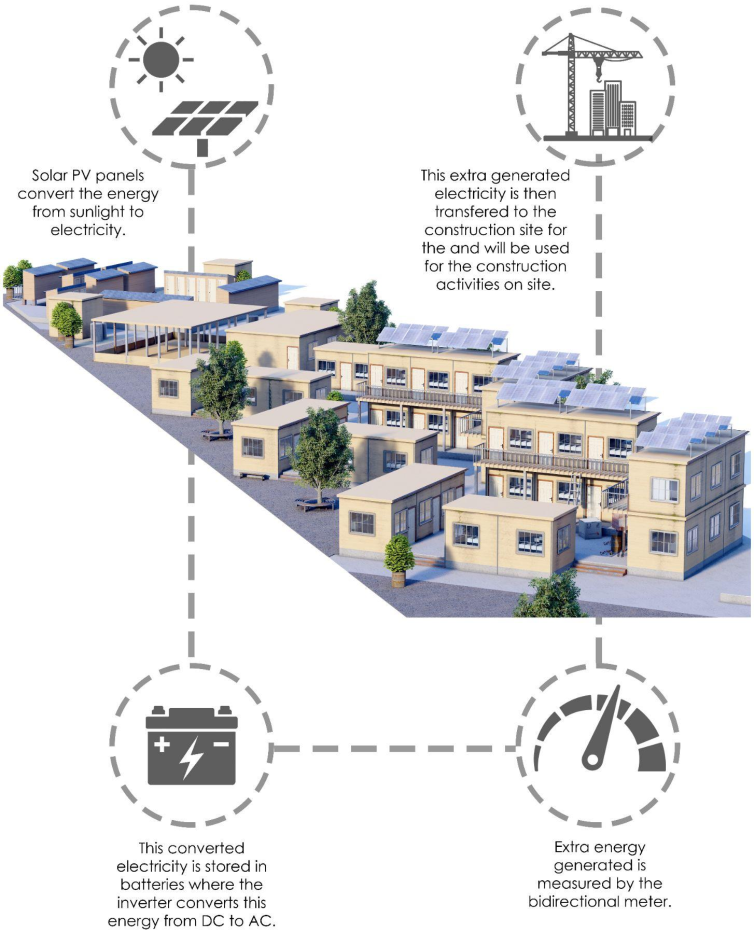


Fig 6.10.3.2 Solar Energy to Electricity Generation

6.10.3.1 On-Site Renewable Energy Generation By Solar PV-

		Inverter		
Inverter Capacity	Peak Load * 1.3			
	7231.9			VA
	7.23			**kVA**
		Solar Panels		
Solar Panels	Wh*1.3/Sun Peak Hours			
	7136.42			**Watt**
No. of Panels	28.55			
No. of Panels	29 Nos			
		Battery		
Battery	Wh*1.3/(Efficiency*DOD*V)			
	1045.37			Ah
No. of Batteries	**5.23**			**of 200Ah**
No. of Batteries	**5 Nos**			

Total Panels= 29 nos.	
Total Voltage= 29*37.8	
1096.2	>450
If we do Series Arrangement	
So, we use series-parallel combination	
Voltage of 8 Panels in a Series= 1096.2/3	
	365.4 V
Connect 8 Panels in 3 series of 8 panels each	

Solar PV Cost calculation	
Size of Power Plant	14.7kW
Cost of the Plant	Rs. 462656 Rs./kW
Total Electricity Generation from Solar Plant	22050 kWh
Financial Savings: Tariff @ Rs.4.67/kWh (for top slab of traffic) per annum	Rs. 102973.5

Connect these 3 strings in parallel to give 365.4 V of output which is less than 450Vdc

Table no. 6.10.3.1.1 - On-site renewable Energy Generation by Solar PV

6.10.3.2 Energy Simulation Inputs-

Input Parameters	Units	Proposed Design Values
General		
Building Area	Sq.m	398.96
Conditioned Area	Sq.m	398.96
Electricity Rate	Inr/kWh	4.67
Natural Gas rate	Inr/Gj	
Building Occupancy Area	-	398.96
Average Occupant Area	Sq.m/Person	2.65
Internal Loads		
Interior Average Lighting Power Density	W/Sq.m	7
List of Lighting Controls	-	
Average Equipment Power Density	W/Sq.m	10
Minimum OA Ventilation (Building Average)	l/Sec.Sq.m	
Envelope		
Roof Assembly U Value	W/Sq.m-K	0.36
Roof Assembly SRI		
Average Wall Assembly U value	W/Sq.m-K	0.36
Window to Wall Area Ratio	%	11.23
Windows U Value	W/Sq.m-K	0.16
Windows SHGC		0.58
Windows VLT	%	0.72
Infiltration Rate	ac/h	0.75
Describe Exterior Shading Devices		Projections and overhangs in the form of passages on the first floor, Jali fenestration to the window to cut off direct sunlight.
Service Hot Water		
SHW Type and Description	-	Solar Water Heater Capacity 400LPD

Table no. 6.10.3.2.1 - Energy Simulations Input

6.10.4 Biogas Plant-

The project aims to have an independent self sufficient system for all the kitchen activities. An efficient set up of a biogas plant is done on site. This biogas plant converts organic waste from human excreta and bio-waste generated from kitchen into natural gas which is a medium for renewable energy in terms of fuel for the all the cooking activities.

An average human generates 0.5kg of waste per day. This generated waste for 150 workers is collected and taken to preliminary storage tank. This waste is then broken down into smaller fragments in a crusher tank. This crushed waste is then taken forward to a mixing unit where it is mixed uniformly for generation of a single mass. This mass generated is taken to the digester unit where the waste generated is converted into natural gas. This natural gas is stored in a gas holder.

Thus the cycle of conversion of waste to energy is a continuous process. By this waste generation the project, generates 19.79 cu.m per day.
The project, in a span of 1.5 years completes its payback period as compared to regular outsourced LPG gas cylinders.

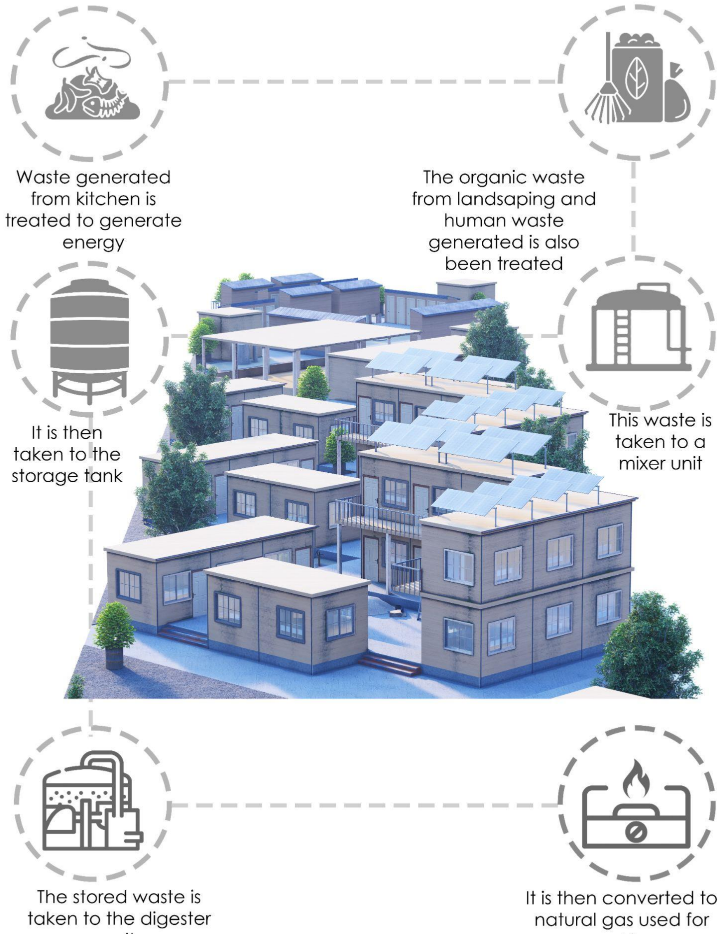


Fig 6.10.4.1 Biowaste to Energy Generation

6.10.4.1- On-Site Renewable Energy Generation By Biogas Plant-

On- site Organic Waste generation				
1 Workers	0.5 kg		1 kg = 0.3 M3 Biogas	
150 Workers	75 kg		75 kgs = **22.5 M3 Biogas / Day**	
Energy Consumption on site				
Calorific Value	LPG	55 MJ / KG		**Duration**
Size	1LPG	47.5 MJ		
Energy	5 LPG	47.5 X 5 X 55	**13062.5**	Ideally a month
			435.42	**MJ /day**
Calorific Value	Biogas	22 MJ / M3		
Amount of Biogas generated			435.42 MJ / 22 MJ/M3 = 19.79 M3	**/day**
Amount of biogas needed < Amount of biogas generated on site				
Collector and Digester size				
Collector size	25 M3			
Digestor (1M3 = 0.7 M3)	36 M3			
Cost Analysis				
(25+36)X4000 = 2,44,000 Rs	Biogas Plant		HDPE = Rs 4000 / M3	
268400	Misc. = 10%			
177480	Cylinder (Per Year)			
PAYBACK	2,68,400/1,77,480		**1.5 Years**	

Table no. 6.10.4.1.1 - On-site renewable energy generation by Biogas Plant

6.11 Water Consumption Estimate-

The net-zero water focuses on the 3 R's i.e. reduce, reuse and recycle from the water consumed on the site. The water collected from the natural sources will be harvested and used for drinking. The grey water will be use for landscaping, washing and other supplementary purposes.

Domestic Use PCPD	
Use of LPD per Head	95
No. of People	150
Total LPD	14250

Table - 6.11.1 Domestic Water Calculations

Catchment Area Calculations		
Water Harvesting Sources	Area	Runoff Coefficient
Roof Surfaces	294.72	0.85
Effective Catchment Area		**250.51**

Table - 6.11.2 Catchment Area Calculations

Months	Rainfall (mm)	Effective rain (mm)	Harvested rainwater (l)
July	163	158	46566
August	129	124	36545
September	155	150	44208
October	68	63	18567
November	28	23	6779
December	4	0	0
January	0	0	0
February	3	0	0
March	2	0	0
April	11	6	1768
May	40	35	10315
June	138	133	39198
			203946

Table - 6.11.3 Rainwater Harvesting Calculations

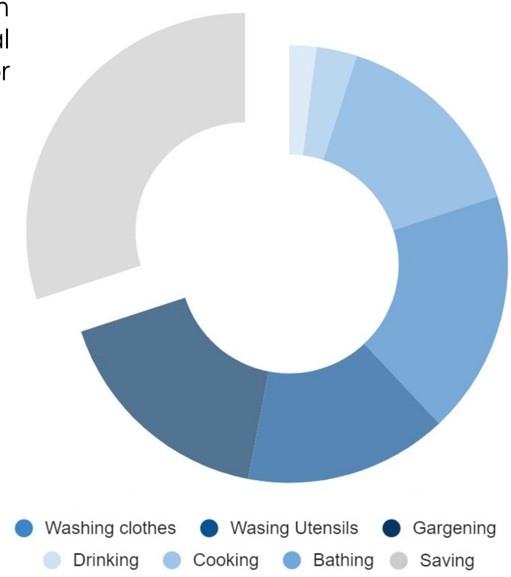


Fig 6.11.1 - End User Water Consumption

6.11.1 Annual Water Calculations-

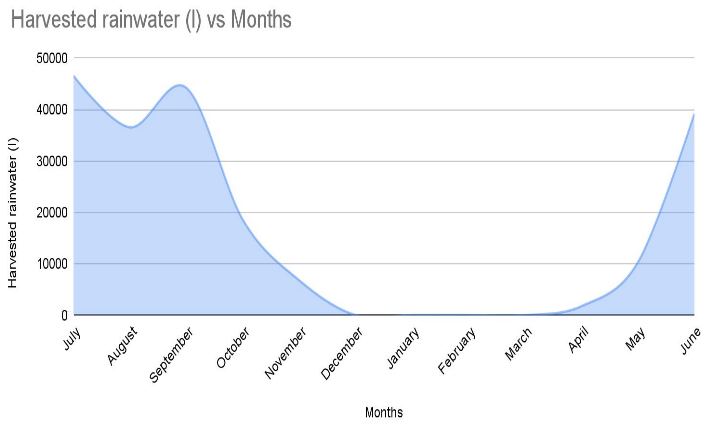


Fig - 6.11.1.1 Rainwater Harvesting Calculations

Occupant's Activity	Percent usage	Quantity (L)	Grey water	Black water
Bathing	15.0%	2137.5	100%	-%
Washing	18.0%	2565	100%	-%
Drinking	2%	285	-%	100%
Cooking	3%	427.5	-%	100%
Toilet	-%		100%	-%
Washing Utensils	17.0%	2422.5	100%	-%
Medical Faility	14.00%	1995	-%	100%
Gardening	1.00%	142.5	100%	-%
Total		9975		

Table - 6.11.1.1 Rainwater Harvesting Calculations

In order to calculate the total amount of water stored and utilized on site, a detailed chart is made indicating the total water consumption during rainy and non rainy months. Based on the water sources available, it is made sure that the water source for each month suffices the amount of water need in the form of stored water thus, making it net-zero.

Consumption								Water Sources			
Month	Days in Month	Domestic Use (L)	Cooling Use (%)	Cooling Use (L)	Irrigation Use (%)	Ittigation Use (L)	Total Consumption (L)	Municipal Water (L)	Rainwater (L)	Grey Water+Black Water (-%) (L)	Total Water Stored (L)
July	31	2945	0%	0	5%	147.25	3092.25	14250	46566	309225	366948.75
August	31	2945	0%	0	10%	294.5	3239.5	14250	36545	309225	356780.5
September	30	2850	0%	0	30%	855	3705	14250	44208	299250	354003
October	31	2945	0%	0	50%	1472.5	4417.5	14250	18567	309225	337624.5
November	30	2850	0%	0	50%	1425	4275	14250	6779	299250	316004
December	31	2945	0%	0	90%	2650.5	5595.5	14250	0	309225	317879.5
January	31	2945	0%	0	90%	2650.5	5595.5	14250	0	309225	317879.5
February	28	2660	0%	0	90%	2394	5054	14250	0	279300	288496
March	31	2945	0%	0	90%	2650.5	5595.5	14250	0	309225	317879.5
April	30	2850	0%	0	90%	2565	5415	14250	1768	299250	309853
May	31	2945	0%	0	90%	2650.5	5595.5	14250	10315	309225	328194.5
June	30	2850	0%	0	5%	142.5	2992.5	14250	39198	299250	349705.5
Total							54572.75	171000	203946	3640875	3961248.25

Table - 6.11.1.2 Annual Water Calculations

6.11.2 Site Level Water Preservation Strategies-

To meet the target of net- zero water module, strategies such as rainwater harvesting, ground water recharge through recharge pits, root zone treatment are used. These techniques help in reducing the daily water consumption by minimizing the wastage of water, and recycling the grey water with the help of sand filters, to reuse it for the purpose of washing and landscaping.

UGT Calculations-

Total fresh water demand in the month of May = 2945 L
Per day demand in May
= 2945/31L
=95 L
Maximum water stored in May
= 5595.5
Per day water stored
= 5595.5/31L
= 180.5 L

Result: The storage tank capacity is twice the required.

Total storage tank capacity = 180.5 L
= 190 L
Size of UGT = 5m x 3m x 2.2m

Since the capacity of UGT is twice of what is required, the building satisfies the condition of being a net-zero water- positive building.

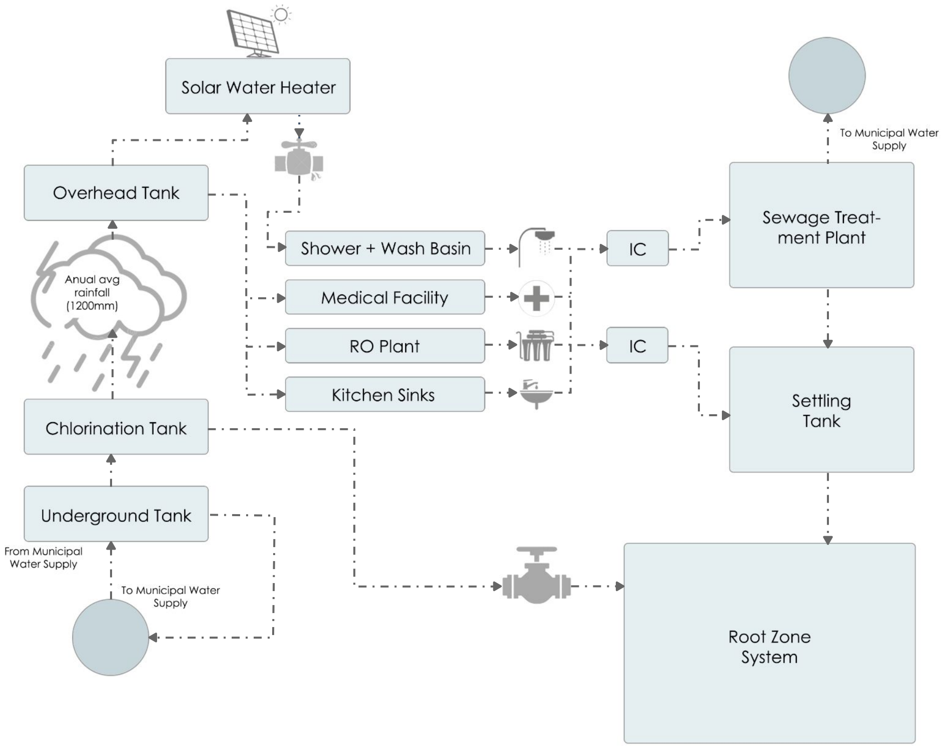


Fig 6.11.2.1 - Water Cycle Diagram

6.11.3 Root Zone Treatment-

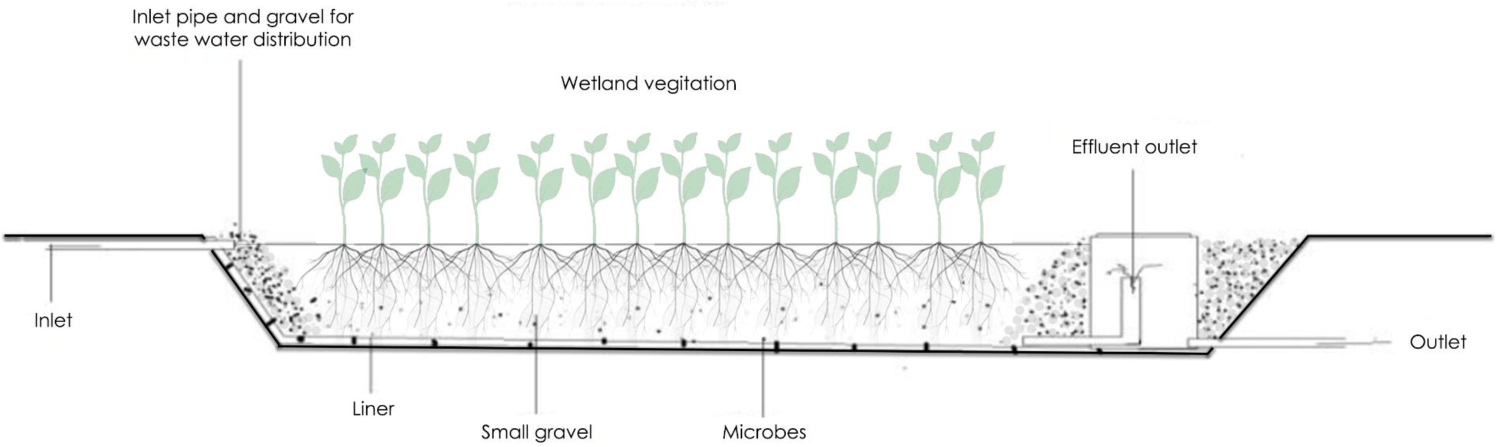


Fig 6.11.3.1 Root Zone system

The rainwater stored using root zone treatment will be further used for the purpose of washing and gardening. The rainwater is collected in the harvesting tanks and is further transferred to the inlet ditch. This inlet ditch consists of reeds and impermeable clay or synthetic lining. The water gets purified at a primary stage as the effluents and solid matter is sieved. Further ahead, the effluents are taken out through the effluent outlet and the filtered water is supplied back to the end users.

6.11.4 Recharge Pits-

The rainwater harvesting is done on site for recharging the ground water by the use of recharge pits. The rainwater draining off from the roof and ground surfaces is collected in these recharge pits with the help of downtake pipes and surface drains. A total of 203.94 kL of water is harvested annually with these recharge pits. Further, as per requirement this recharged water is drawn by the use of hand pumps. These hand pumps reduce the wastage of water by limiting the usage as per the need. This cycle thus, goes on repeating and this helps meet the strategy of making the project water efficient.

6.12 Resilience-

6.12.1. Identification of risks corresponding to the location:

The modules would have to face climatic conditions due to floods, earthquakes, heavy rainfall, etc.
Flash Floods: The location may face flash floods due to the irregular pattern of rainfall throughout the Pune region, posing a threat to the worker housing and other buildings in the surroundings.
Earthquakes: Pune lies very close to the seismically active region of Koyna Dam located to south of the city. The region is rated in the Zone 4 category. This is an immediate concern for the structure and its surroundings.

Fire Hazards

Flash Floods

Earthquakes

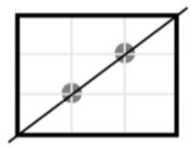
6.12.2. Building Performance:

The worker housing has been designed through evidences based on calculations and simulations on various softwares and case studies of net zero buildings. All of this was to make the individual feel comfortable even during harsh climatic conditions. The design strategies like open to sky courtyards- work as interaction space within the building clusters, the building orientation opens the spaces up to breathe and increases the wind flow throughout the site. The use of wall materials with low U-values and structural framework reduce heat gain and make the interior spaces much cooler, enhancing the thermal comfort.

6.12.3. Identification of strategies to overcome the risks corresponding to various disasters:

1. Symmetrical Design:

The buildings are divided into clusters with a centrally located open to sky courtyards which facilitate optimum wind flow throughout the site, the structure is modular which is designed on a grid while the structural framework reinforces the walls. The symmetry increases the resistance against earthquakes.



2. Elevated Structure:

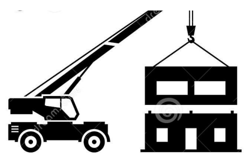
The modules have a plinth of 0.45m considering the climate of Pune, which would be essential for tackling the flash flood situation. Several waterproofing elements such as waterproof coat on panels, precast concrete panels for plinth are also incorporated in the design. In case of floods the base of the eucalyptus panel may get decay and may require a replacement.

3. Fire Resistant:

Fire hazards are one of the few common man-made disasters. The panel has a property of fire resistance. The air cavity acting as an insulation in wall module helps retardation of time during the case of fire. The issue has also been taken care by fire resistant door panels while the staircases are centrally located within the clusters to facilitate the fire escape routes throughout the site. Fire extinguishers and sand buckets are placed at strategic locations throughout the site.

4. Earthquake Resistant:

The modules of the clusters are strengthened by structural framework of L-angle steel beams and cross stanchions providing ductility to the structure. The system helps in preventing the building to bend, sway and deform without collapsing.



4. Water and Electrical shortage:

In case of water shortage mostly during the summers, will be catered by the additional 10,703 LPD that will be used on site.
In case of power cut offs the structure will sustain over the additional energy generated by the solar PV panels 13272.4 kW hr. Thus, the panels generate an additional energy of 1.51 kW hr per day which can be used during the shortages.

5. Isolation Wards:

In the midst of the Corona pandemic, the patient load on hospitals and clinics has increased. To tackle the situation, the modules can also act as isolation ward for the infected people at a secluded space. The furniture arrangement would be different in the scenario and would be according the COVID19 norms.

6.13 Affordability-

- Design strategy are used for optimizing the cost of construction is simple modular construction .
- To reduce the cost, we have used foldable benches as it is cheaper and will require less space.
- We have also used Led tubelight in place of normal tubelight. LEDs are initially expensive, the cost is recouped over time and in better energy savings. LED light bulbs use only 2-17 watts of electricity (1/3rd to 1/30th of Incandescent or CFL).
- To decrease the time period we have used Modular construction.
- We are saving around 5 lakhs compared to base case where the total costing was 25.2 lakhs and we proposed design case which can be executed in 20.05 Lakhs.

6.13.1 Modular Construction Advantages : -

- **Speed of construction/faster return on investment :** Modular construction allows the building and the site work to be completed simultaneously. According to eucalyptus panels modules, plinth material, materials, this reduces the overall completion schedule by as much as 50%. This also reduces labor, financing and supervision costs.
- **Indoor construction :** Assembly is independent of weather, which increases work efficiency and avoids damaged building material.
- **Ability to service remote locations :** Particularly in countries in which potential markets may be located far from industrial centers there is a much higher costs to build a site-built house in a remote area or an area experiencing a construction boom such as mining towns. Modular buildings are also beneficial in providing medical and sanitary facilities where time, space, and money are an issue.
- **Environmentally friendly construction process :** Modular construction reduces waste and site disturbance compared to site-built structures. The controlled environment of the factory allows for more accurate construction while allowing the extra materials to be recycled in-house.
- **Flexibility :** When the needs change, modular buildings can be disassemble and the modules relocated or refurbished for their next use reducing the demand for raw materials and minimising the amount of energy expended to create a building to meet the new need. In essence, the entire building can be reused in same climatic condition.


Indoor Construction


Environmentally Friendly


Remote Location


Reuse the module


Speed of construction

6.14 Innovation-

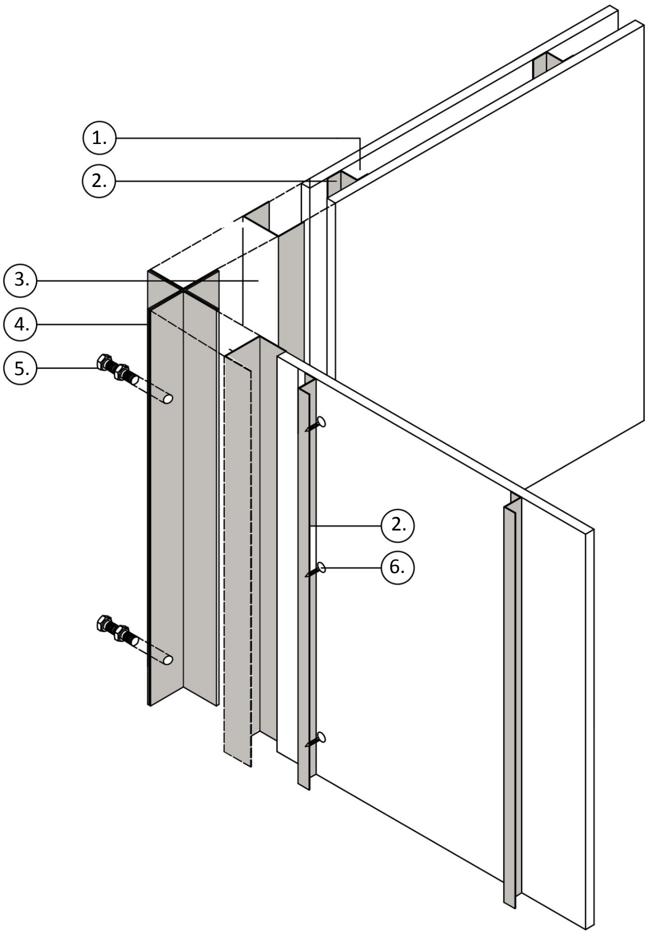
- The onsite labour housing demands modular, affordable, thermally comfortable and hygienic environment.
- Thus, Nest aims in achieving these goals through identifying existing issues, working out possible innovative methods and coming up with best suitable strategies and design.
- Considering this as a temporary low cost housing, the design tries to break the ordinary conceptions about worker housing colonies and facilitates the stay units using the concept of “Best out of Waste”.

6.14.1 The Plinth and Foundation:

- The conventional practice of concrete plinths requires to be knocked down/demolished during the shifting of these sheds, adding to the cost.
- This current practice is replaced by 300mm thick excavated debris from the ongoing metro construction site with a coat of 8mm thick cement slurry acting as a waterproof layer.
- Thus, making it reusable and affordable design.
- A pit of 900x900mm is excavated for columns.
- The precast concrete blocks of 600x600mm are used as column pedestal with a 150 mm thick PCC bed.

6.14.2 The Walls:

- The current labour housing system adapts GI sheets for walls and roof, but these are not suitable for the climatic zones of India and create thermally un-comfortable environment for the labourers. Thus nest proposes self designed module made of Eucalyptus panels which are affordable, biodegradable and thermally comfortable material.
- The GI sheets modules are cannot be efficiently reused. Hence our design with eucalyptus panels act as faces of a cube which are self standing units with specially fabricated cross stanchion This helps in providing easy installation, efficient reusability and effortless dismantlable design.
- The proposed sandwich panel is a combination of 25mm thick eucalyptus panel and a 50mm air cavity. Thus this cavity helps to delay the heat transfer from the outer environment to the inner environment making the module thermally comfortable obtaining the U value of 0.36 W/m^{2}K.
- The edges of the wall are protected using C section preventing the wear and tear.
- The same module of wall is been repeated for the slab.



1. Eucalyptus-Panels(3000x150 x25mm Thick)
2. Z-sections(1200x1500x4mm)
3. C-sections(100x75x2 mm)
4. Equal angle section(4 equal L-angle-sections (100x100x4mm)
5. Hexagonal bolts
6. Screws
7. Air Cavity
8. Mdf Jali (8 mm Thick)
9. FibreGlass (4mm Thick)
10. Base plate (4mm Thick)
11. Precast concrete blocks (600x600x600mm)
12. Anchor bolts
13. Cement slurry
14. Steel Mesh
15. Debris

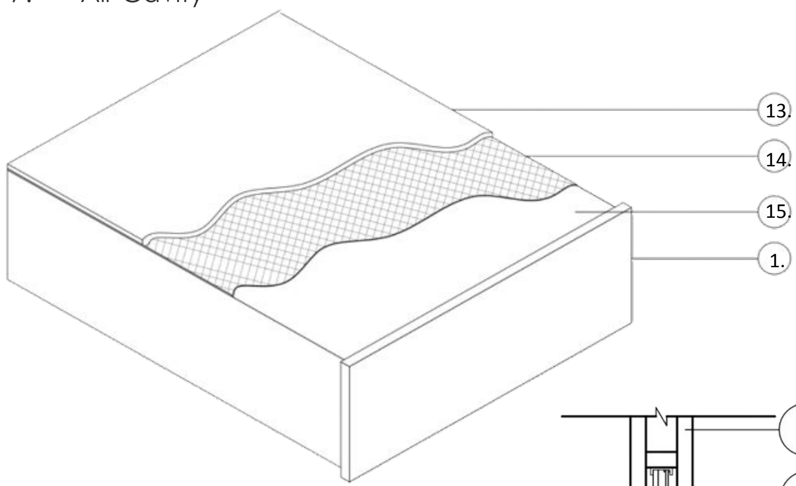


Fig 6.14.2.2 - Detail of Plinth

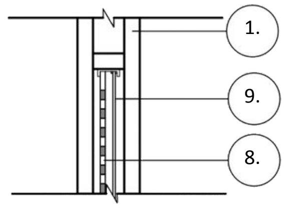


Fig 6.14.2.3 -Window detail

Fig 6.14.2.1 -Eucalyptus wall panel fixing

6.14.3 The window:

- The current use of 4mm glass window design is replaced by a cross section of 4mm thick MDF jali(out) and 4mm fibreglass(in). The jali acts a buffer to channelise the wind flow making the space cooler than the outside environment.

6.14.4 Landscape:

- Instead of using conventional cement/plastic planters, we propose use of packaged wood boxes which also act as seating areas in the common courtyards.
- Substituting soil with cocopits help in reducing the water consumption by 60% monthly.
- Reusable plastic drums are used on site for plantation which makes it easily transportable, reusable and affordable.
- Besides the plastic drums, seating spaces are designed by use of truck tyres making it modular and reusable.
- Grey water is purified by the use of root zone treatment which not only acts as a landscape feature but also helps in reusing the purified water for domestic purposes.

6.14.5 Structural System:

- The designed units of size 3x3m are placed side by side supported by the steel cross stanchion which act as a common vertical support for the system making it modular yet detachable in nature.
- The specially fabricated cross stanchion is of equal L angle section(100x100x4mm) are welded back to back forming a “plus”.
- This assembly allows the flexibility in the module to connect walls at any edge.
- The cavity between the panel maintained by Z sections acting as studs placed at 600mm c/c.
- The slab of eucalyptus panel module rests on a L beam (ISMB 250) and is bolted to the stanchion.

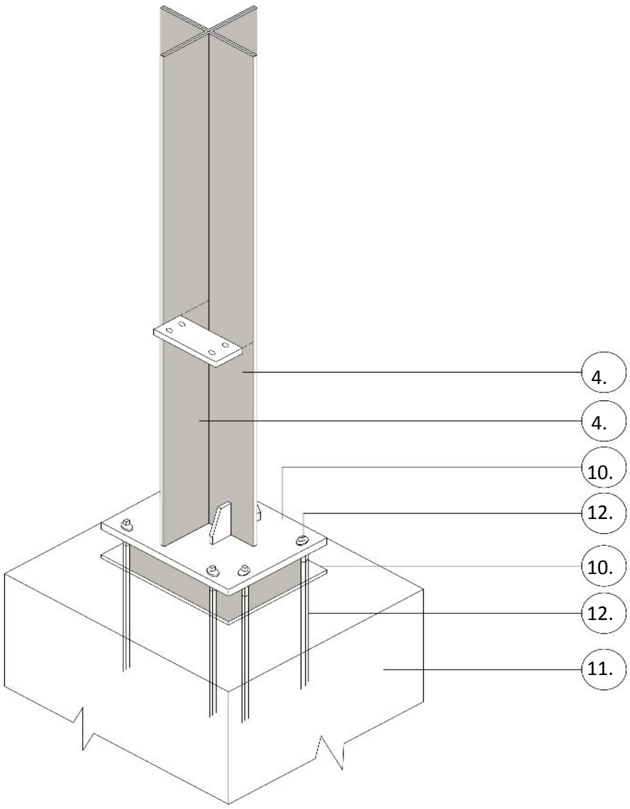


Fig 6.14.5.1 - Fixing of Cross stanchion

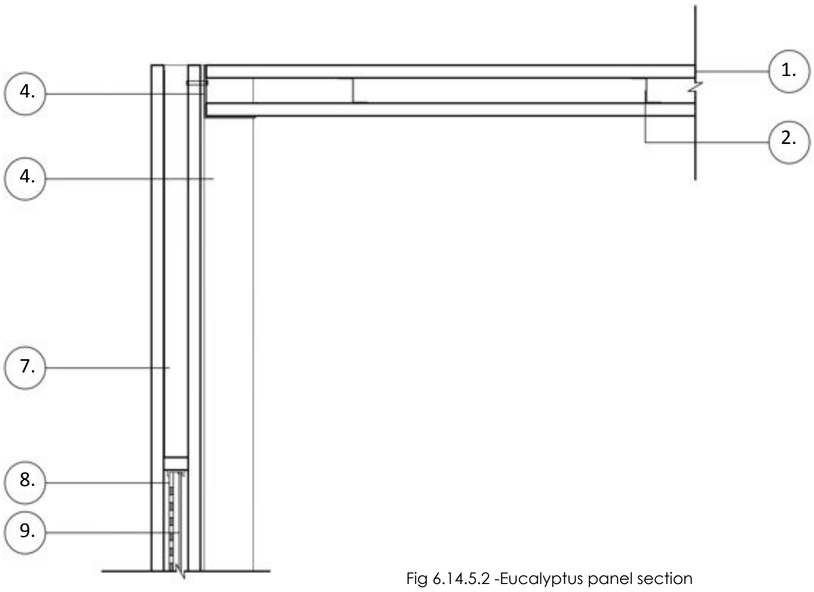


Fig 6.14.5.2 -Eucalyptus panel section

1. Eucalyptus-Panels(3000x1500x25mm Thick)
2. Z-sections(1200x1500x4mm)
3. C-sections(100x75x2 mm)
4. Equal angle section equal L-angle-sections (100x100x4mm)
5. Hexagonal bolts
6. Screws
7. Air Cavity
8. Mdf Jali (8 mm Thick)
9. FibreGlass (4mm Thick)
10. Base plate (4mm Thick)
11. Precast concrete blocks (600x600x600mm)
12. Anchor bolts
13. Cement slurry
14. Steel Mesh
15. Debris

6.14.6 The roof:

- The roof is of eucalyptus panel module with an overhang of 100mm with a waterproof coat. The water collected from the gutter of the roof is treated through rootzone treatment are is percolated in the ground via percolation pits.

6.14.7 Landscape:

- Instead of using conventional cement/plastic planters, we propose use of packaged wood boxes which also act as seating areas in the common courtyards.
- Substituting soil with cocopits help in reducing the water consumption by 60% monthly.
- Reusable plastic drums are used on site for plantation which makes it easily transportable, reusable and affordable.
- Besides the plastic drums, seating spaces are designed by use of truck tyres making it modular and reusable.
- Grey water is purified by the use of root zone treatment which not only acts as a landscape feature but also helps in reusing the purified water for domestic purposes.

6.14.8 Toilet:

- Portable plastic toilet units which are used in labour camps are replaced by biodigester toilet blocks .This design helps in less use of water, better disposal of urea and making the design sustainable .
- These blocks are designed such that the units are supported by a metal grid which is prefabricated and is transportable and dismantlable. Units are made of same wall panels used in residential blocks and roof is made of reusable GI sheets.
- Biodigester toilets is a Maintenance free technology, it has zero discharge of sludge, self re-generation of Anaerobic bacteria by polymers and thus it reduces maintenance issue of drainage soaking.

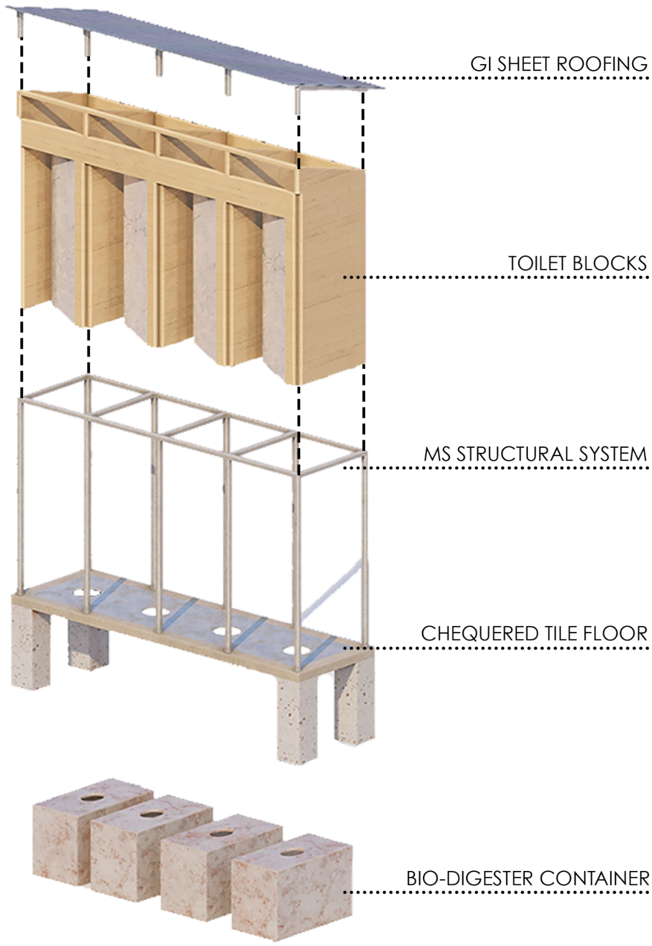


Fig 6.14.8.1 -Toilet fixing detail

6.14.9 Scalability:

- The design being modular it can be repeated multiple time on site and in same climatic zone with certain alterations in the orientation.
- The modules can be placed individually or in combination depending upon the site requirement making it scalable for the market.
- It is easily disassembled and assembled on site helping in faster construction.
- Reusability of the panels is about 15 to 20 times.

Challenges:

- The challenge for the design is that the module would require alterations to make it potential for different climatic zones.
- Additional care needs to be taken for the panels during floods.
- Achieving the stability of the panels is a challenge as it is semi-porous and light weight in nature.

6.15 Engineering and Operations-

6.15.1 Biogas plant:

- An efficient set up of a biogas plant is done on site. This biogas plant converts organic waste from human excreta and bio-waste generated from kitchen into natural gas which is a medium for renewable energy in terms of fuel for the all the cooking activities.
- The mass generated is taken to the digester unit where the waste generated is converted into natural gas. This natural gas is stored in a gas holder.
- Thus the cycle of conversion of waste to energy is a continuous process. By this waste generation the project, generates 19.79 cu.m per day.
- The project, in a span of 1.5 years completes its payback period as compared to regular outsourced LPG gas cylinders

6.15.2 Solar Panels:

- Solar panels of size 1640X992X35mm are fixed on the roof of the residential block. Solar energy is stored in portable gel batteries and converted to AC by use of inverter .
- These batteries are transported to the electrical room on site and are connected to the supply lines which transport electricity to the respective areas .
- The payback period of these solar panels is 1.2years.
- The annual energy consumption of site is 8777.6 KWH per year. Thus 29 solar panels generate 10950 KWH energy per year. Thus the remaining 2172.4 kWh is supplied to the ongoing metro work.
- Advantages of using LED bulbs instead of CFL is that it helps in better environmental performance and energy efficiency .Thus annual saving is Rs 51136.5 .

6.15.3 Electrical layout:

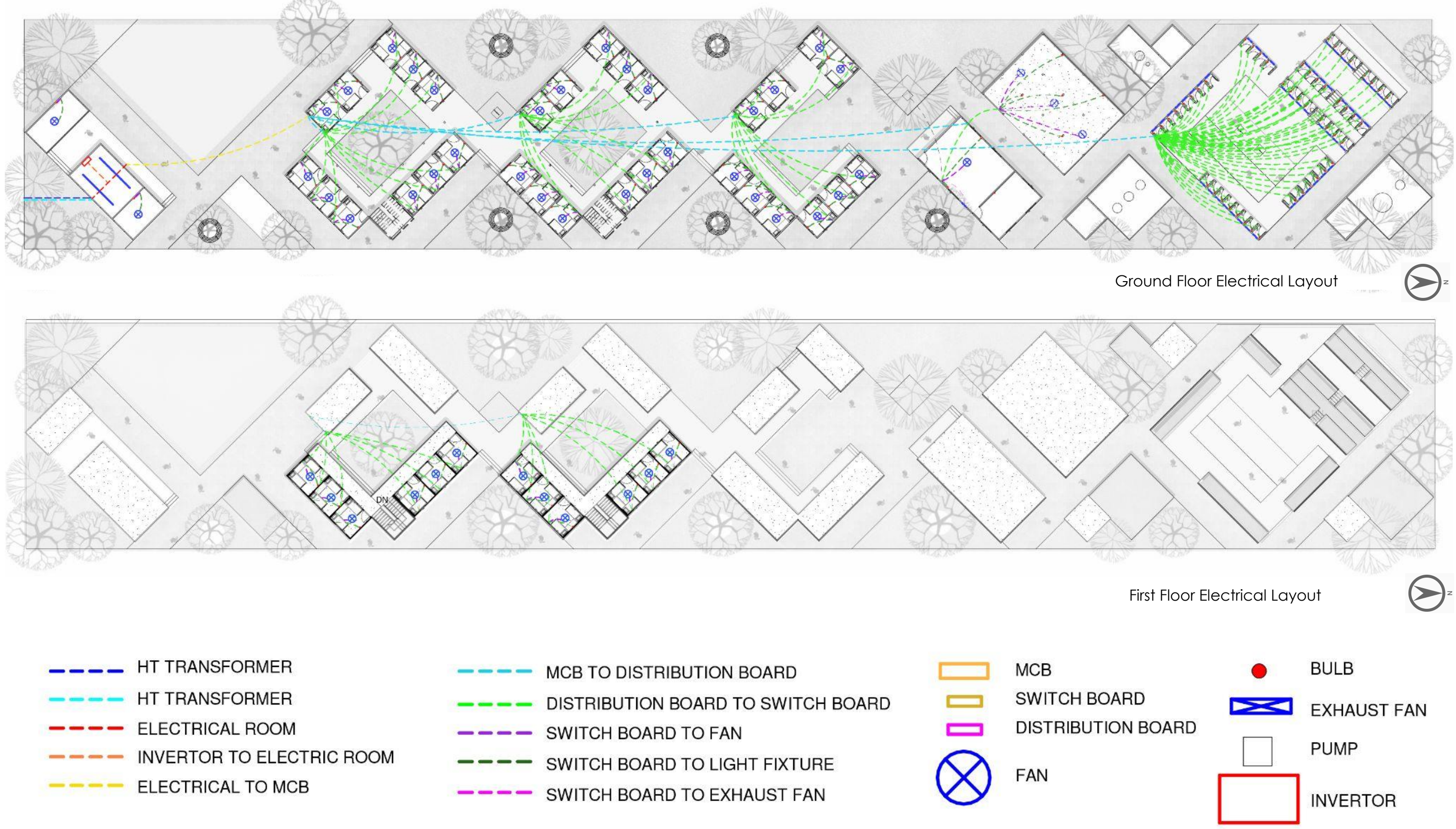


Fig 6.15.3.1 - Electrical Layout

6.15.4 Plumbing layout:

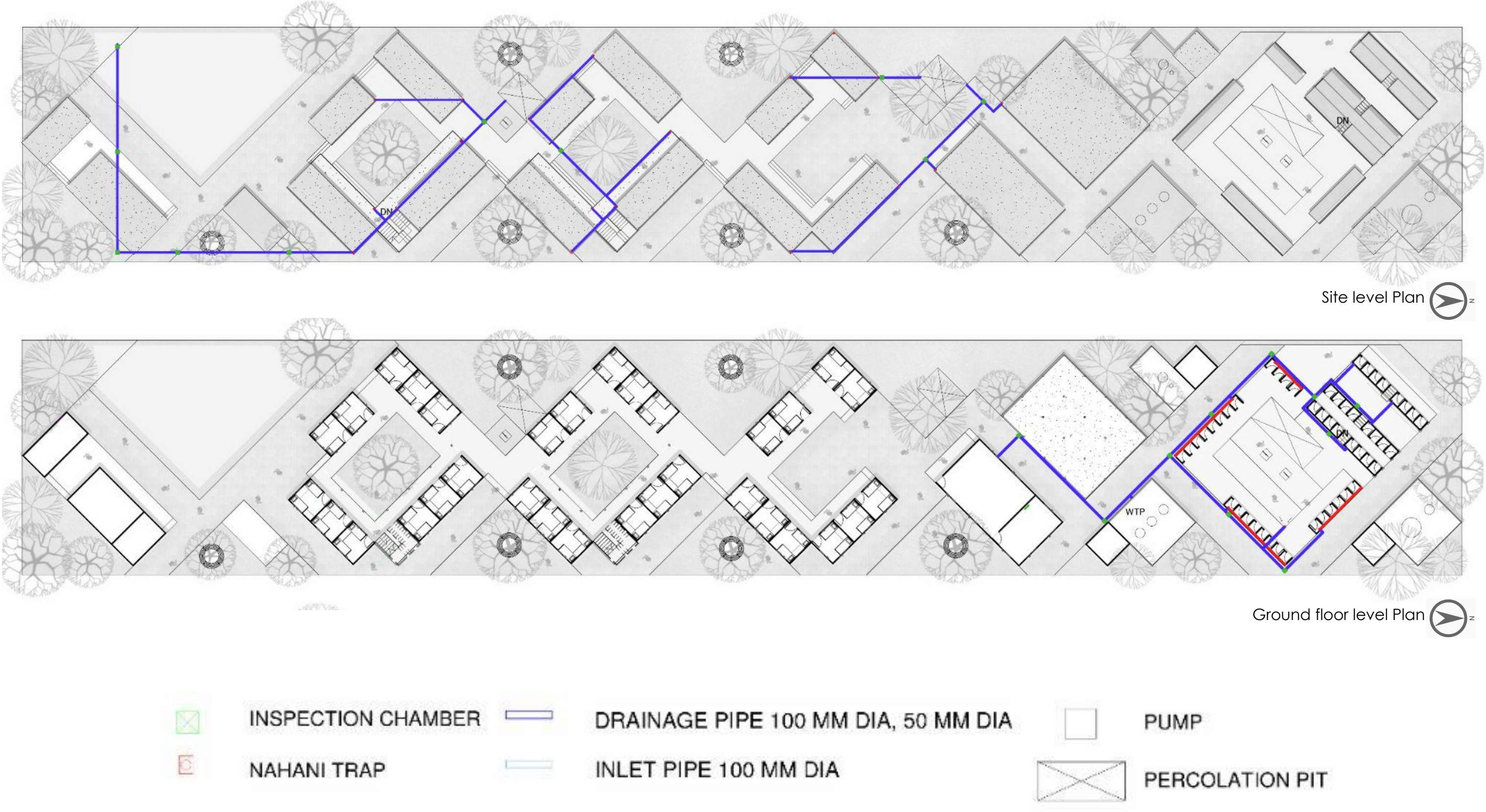


Fig 6.15.4.1- Plumbing Layout

6.16 Scalability and Market Potential-

- Developing nations have a scope and potential for the infrastructural growth. In India, there is a rapid increase for the need of private and public infrastructure to be constructed.
- These projects, be it large or small scale, are executed by these on-site workers, providing them employment and liveability. Here in India, many immigrants live in unhygienic and uninhabitable conditions on the site.
- Hence, there is a need to propose a better design solutions for them.
- As the current government has proposed many infrastructural projects and has been allocating better budgets for public infrastructure, we think that with these projects the concern for labour housing should also be taken in the consideration.
- Hence, targeting these government projects for these proposed worker housing is the way we can emerge and scale these projects widely.
- Once most of the government projects practice this system awareness for the need of a well designed and well executed worker housing could be spread.
- Schemes can be proposed by government where private developers can get an incentive for including these solutions in their projects helping them cut down the cost yet providing them with better liveable conditions.


Best out of Waste


Modular Construction


Ease of Use


Comfort

- As the design is 100% dismantlable, reusable, and transportable, it can be easily implemented in any part of the nation with slight modifications considering the geographical conditions.
- On- site Mobility of the housing becomes feasible and quick by the use of the modular elements.
- The infrastructural shift towards sustainability for all building typologies including the construction labour housing, provides an increase in the more efficient working of the material suppliers with an increase in the production rate.
- Improving the conditions and standards for the workers will help in the increase in employment rate of the nation.
- The use of modular construction using Eucalyptus panels and steel framework has been used thus, improving the quality of life for the labours in terms of thermal comfort, health and wellbeing, etc. along with saving time and cost.
- There are no complex joineries introduced in the assembly, hence boosting the speed of construction.
- The design of units provides the flexibility of walls to be reinstalled creating a different space, for example, the two units of 3x3 m can be easily converted to a dormitory by removing the shared wall of the two.
- The use of Eucalyptus panels, excavated soil debris, precast concrete pedestals, plywood formwork, etc. contributes and justifies our vision of 'best out of waste'.
- These strategies helped us achieve the annual energy consumption to 8777.6 kWh.
- The on-site renewable energy is generated using Solar PV panels and biogas plants (again reusing the organic waste generated around the site) supplying electricity to the appliances and lightings through connectors.
- The excess energy generated is also being used on construction site.
- The investment on the designed labour colony is 20 lakhs with the increase in payback period and reduction in the maintenance cost as compared to the conventional method having an investment of 25.2 lakhs.

6.17 Comfort and Environmental Quality-

6.17.1 Relative Humidity and dry Bulb Temperature

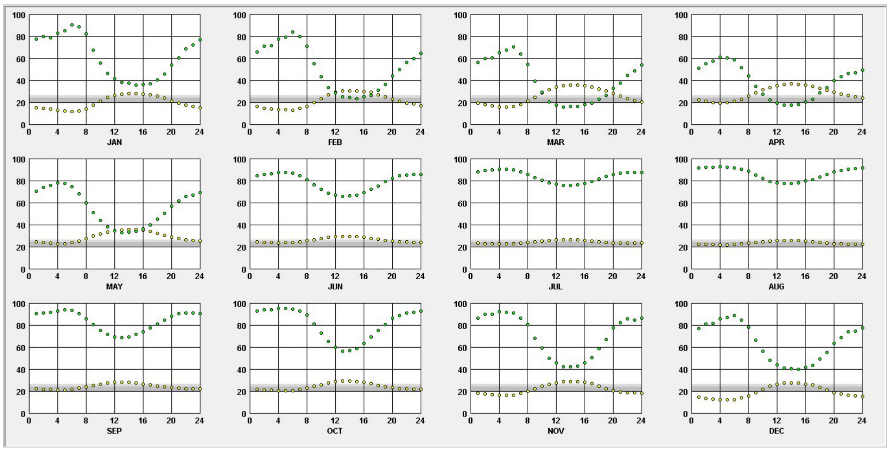


Fig 6.17.1.1 - Dry Bulb Temperature and Relative Humidity

- The relative Humidity and Dry Bulb Temperature from the above graphs can be observed to be comfortable for an occupant during the month of February, March and April for composite climate.
- The range between 20 to 25 for summers and winters respectively is considered to be ideal for relative humidity and dry bulb temperature.

- **Design considerations** -Designed units should be in correlation with RH table above where RH and dry bulb temperature values coincide for a longer period yearly .

6.17.2 Psychrometric Chart

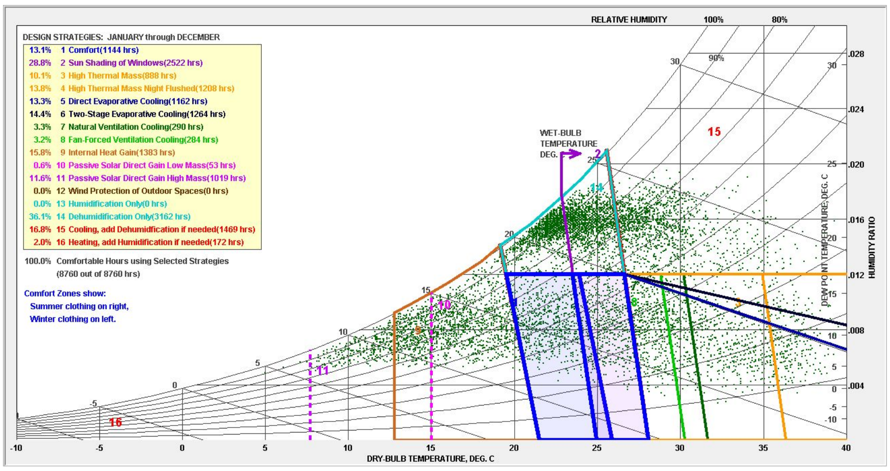
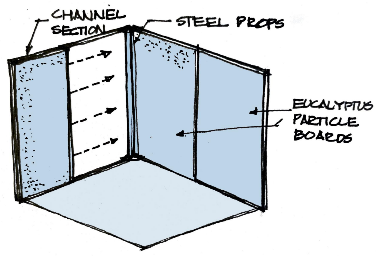


Fig 6.17.2.1 - Psychrometric Chart

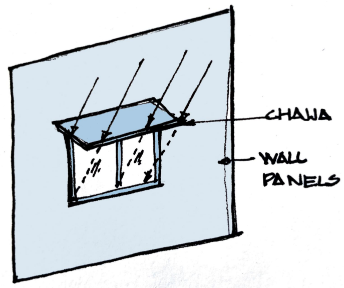
- The psychrometric chart demarcates the strategies best suited for designing in composite climate-
  - Sun shading windows
  - Buffer Spaces
  - Effective cross ventilation
  - Mutual shading between buildings

- **Design considerations** -Considering the chart above and the climatic conditions dehumidification factor is added in design along with other strategies .

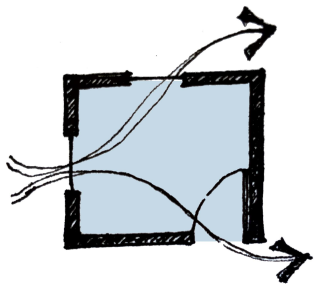
7.2.3 Passive design strategies



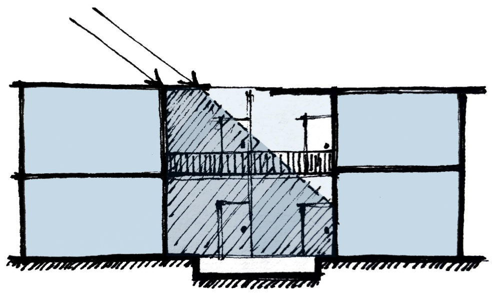
Movable and dismantlable panels used for walls make design flexible and spaces can interchange.



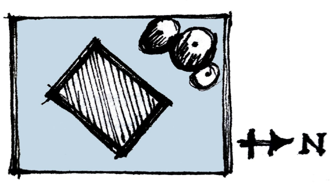
Window overhangs or operable sun shades can reduce or eliminate air conditioning



Good natural ventilation can reduce or eliminate air conditioning if windows are well shaded and oriented to prevailing breezes



Small recessed shaded openings ,operable for night ventilation to cool the mass are used .



The orientation of structure helps in enhancing use of natural light and ventilation

Fig 7.2.3.1 - Passive Design Strategies

6.17.3 Annual Daylight Analysis

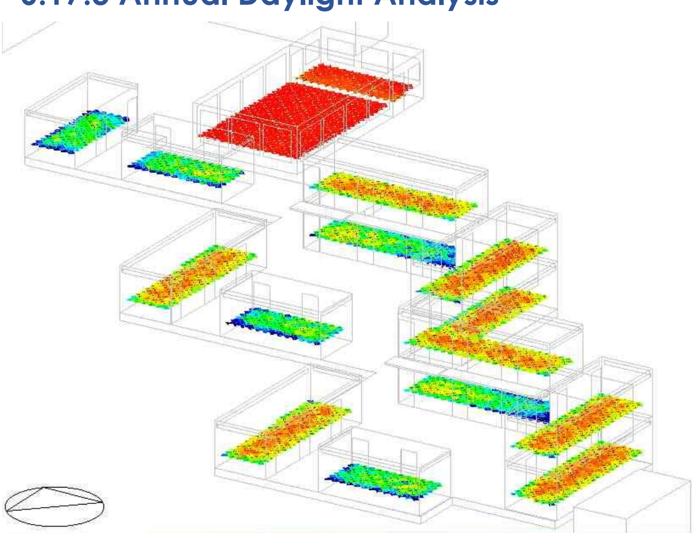


Fig 6.17.3.1 - Annual Day light Base Case Model

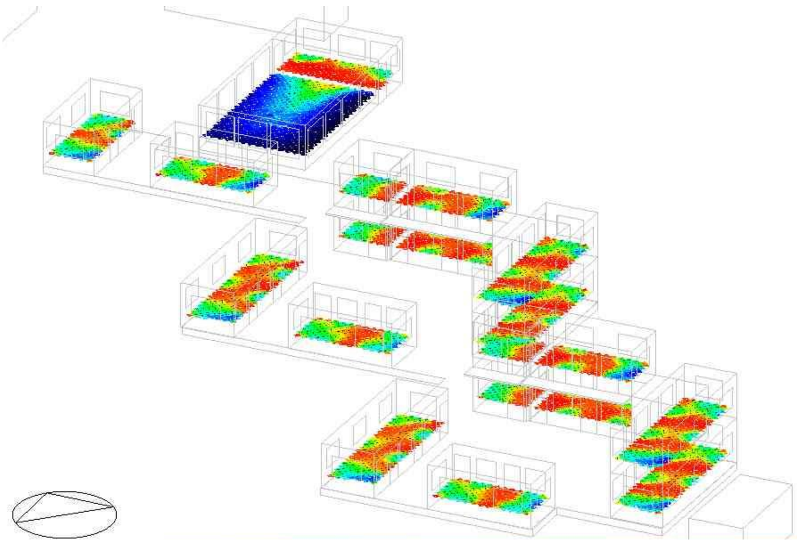


Fig 6.17.3.2 - Annual Day light Design Case Model

Pct Annual Hours	0	8	16	25	33	41	50	58	66	75	83	100

After comparison of the base case and design case, it is been observed that the percentage of spaces gaining natural daylight annually has been increased with about 20%.

6.17.4 Illuminance Analysis

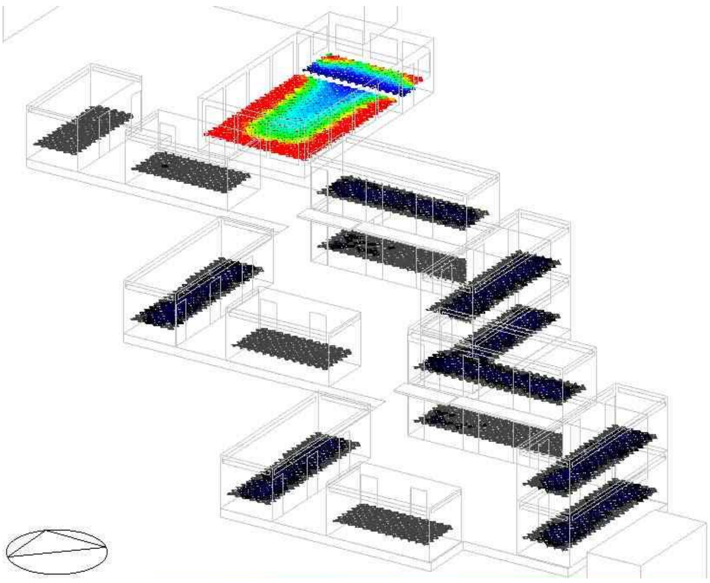


Fig 6.17.4.1- Daily Illuminance Base Case Model

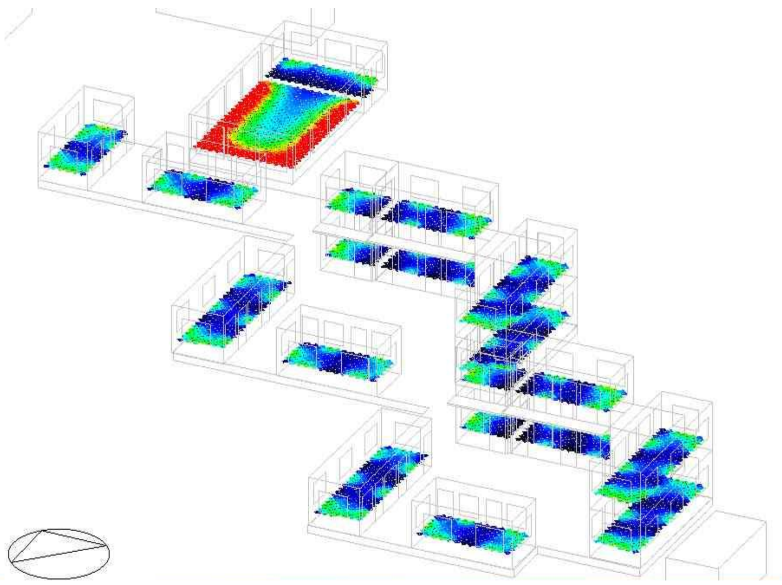
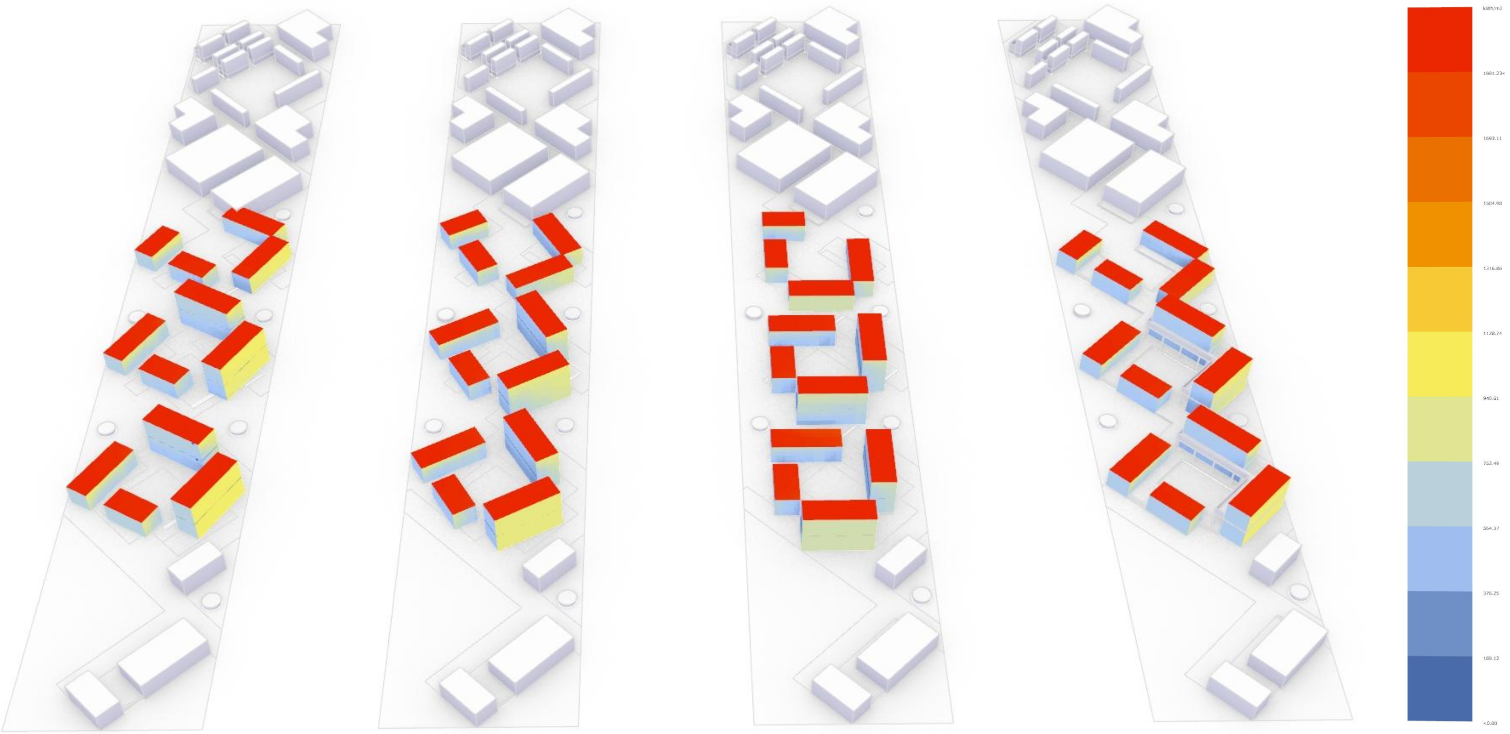


Fig 6.17.4.2 - Daily Illuminance Design Case Model

Illuminance (lux)	110	267	425	582	740	897	1055	1212	1370	1527	1685	2000

The illuminance of less than 110 lux is observed in the base case model whereas for the design case, various strategies like larger openings, shandong devices, screened windows, wtc have been used which provides an illuminance value between 110-300 lux for maximum number of spaces thus providing comfort.

6.18 Solar Radiation Analysis-



Building Orientation 180 Degree

Building Orientation 90 Degree

Building Orientation 0 Degree

Building Orientation 270 Degree

Fig 6.18.1 -Solar radiation analysis

Radiation, Sunlight hours and wind analysis was done for each of the case that is 0 degree, 90 degree, 180 degree and 270 degrees on the basis of gain/loss, sunlight hours, wind flow and space function to ensure efficient building orientation.

6.19 Solar Radiation/Humidity Analysis For Residential Block-

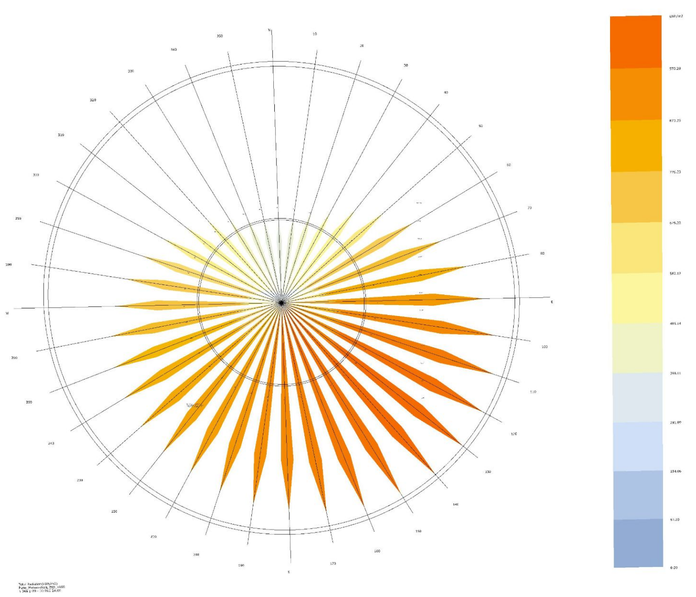


Fig 6.19.1 -Annual Solar Radiation

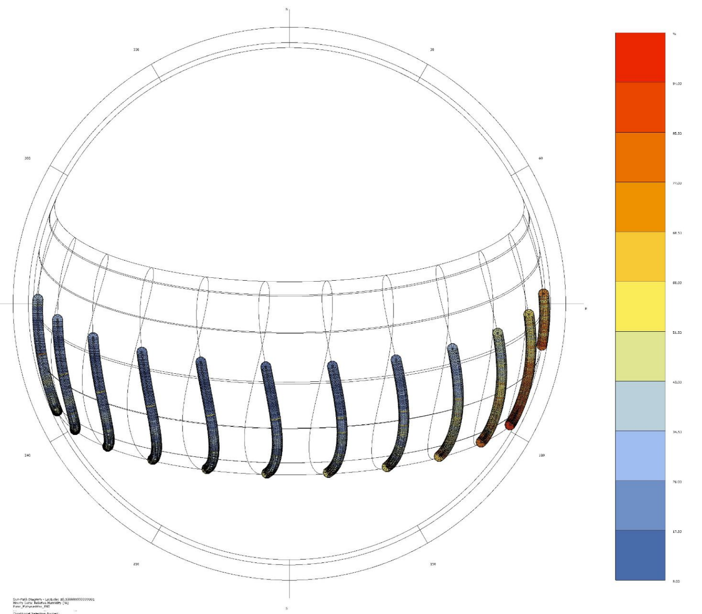


Fig 6.19.2 - Relative Humidity Analysis

6.20 Wind Flow Analysis

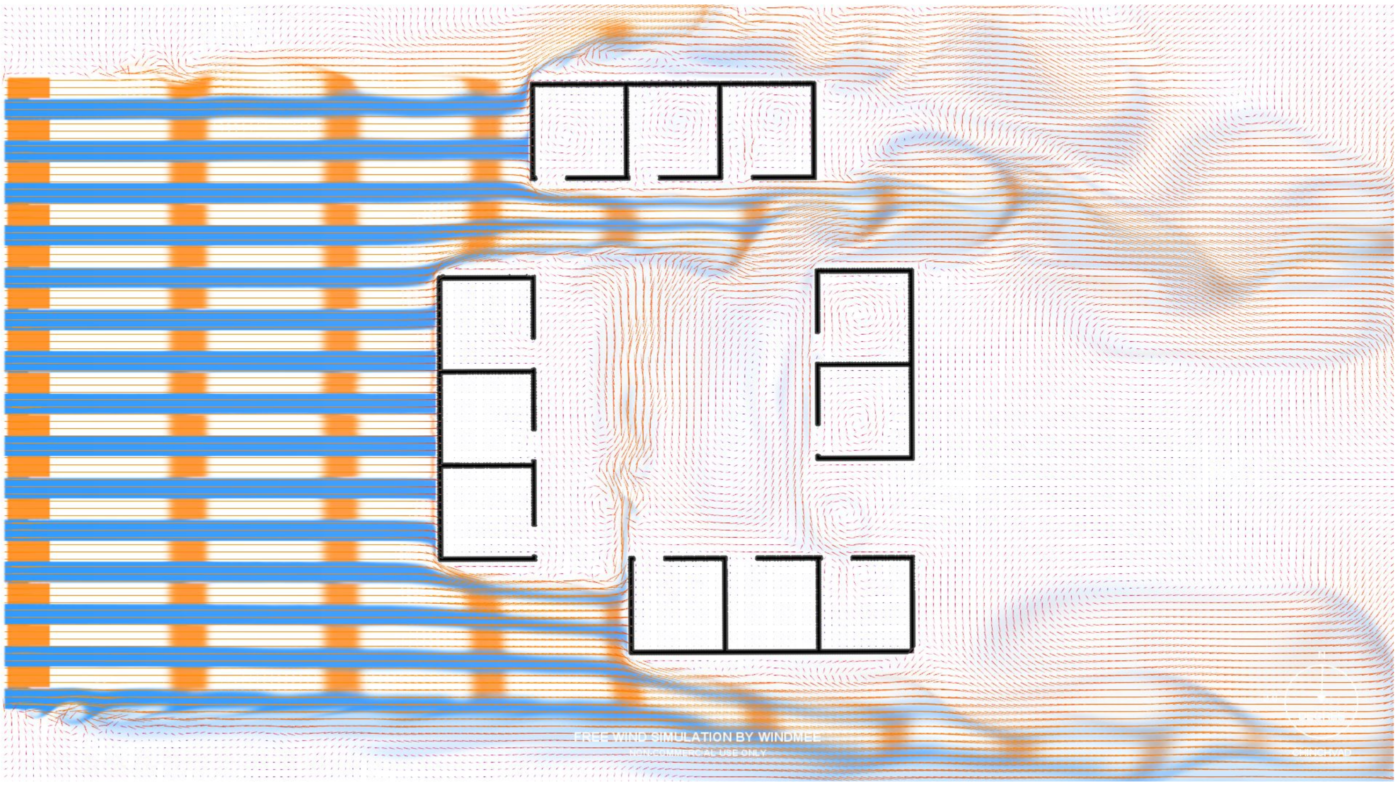


Fig 6.20.1 - Wind Flow Analysis Base Case

Considering the predominant wind direction which is Southwest to Northeast,a wind analysis report is done which inferences that in the base case where there is no provision of openings for wind flow. Hence, this study helps in designing and providing better natural ventilation provision.

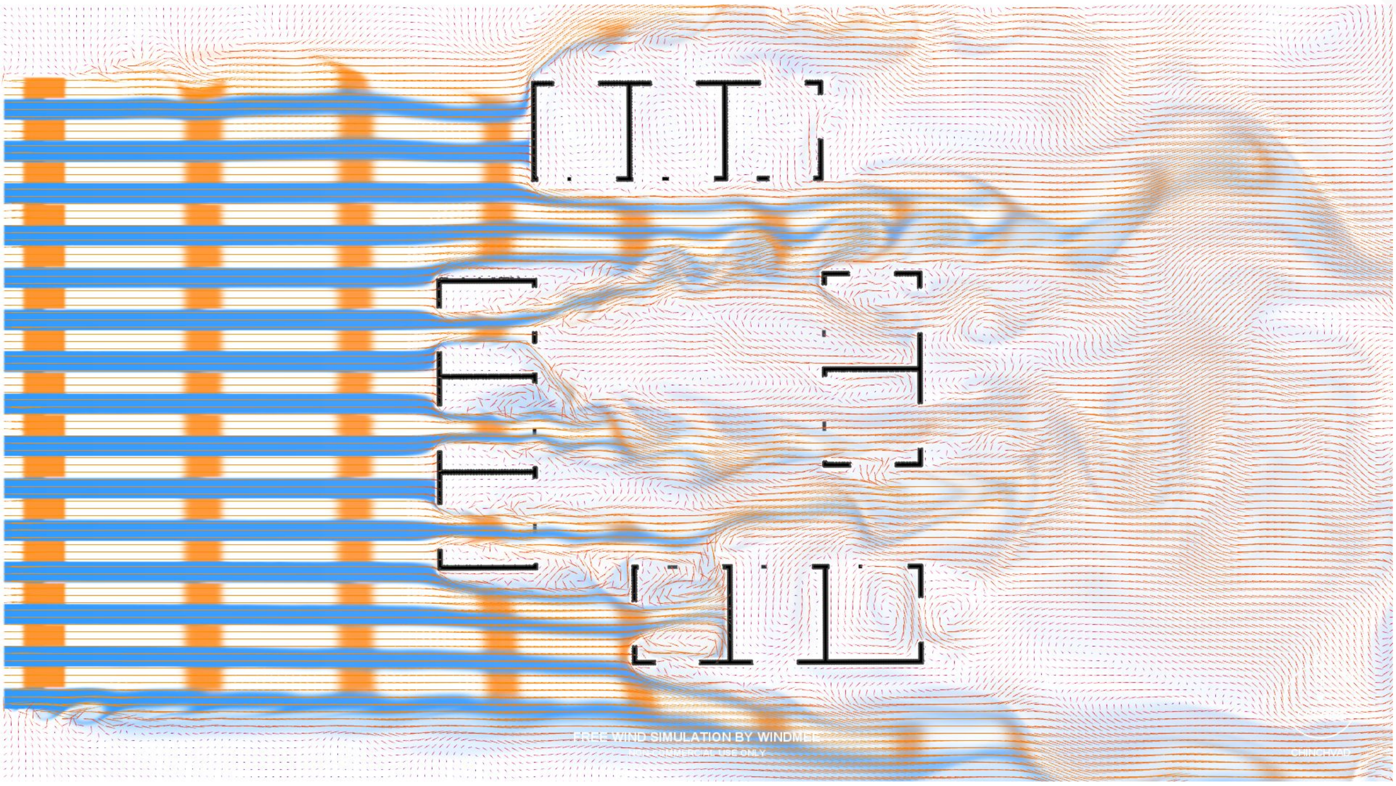


Fig 6.20.2 - Wind Flow Analysis Design Case

After studying the basecase, natural ventilation provisions for design case were provided and simulation report was taken .This report shows us effective wind flow through the cluster and the units making the design well ventilated .

7. References

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