NOVA

ENVISIONING A BETTER WORLD

Solar™ Decathlon India

FINAL DESIGN REPORT

APRIL 2023

On Site Construction Worker Housing

Project partner: Larsen and Toubro

LEAD INSTITUTION:

Jamia Millia Islamia
New Delhi

PARTNER INSTITUTION:

Amity University
Noida

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Team name : Team NOVA

Lead Institute : Jamia Millia Islamia, New Delhi

Partner Institute : Amity University, Noida

Division : On- site Construction Worker Housing (CWH)

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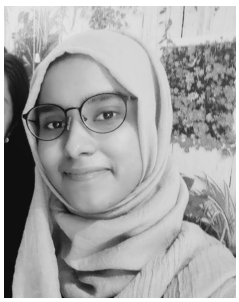

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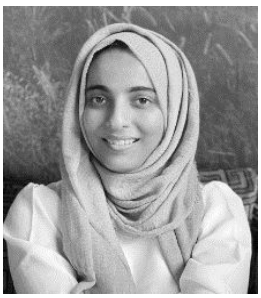

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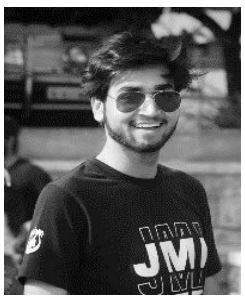

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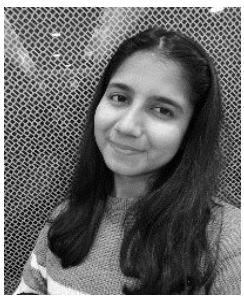

MAHENOOR FATIMA
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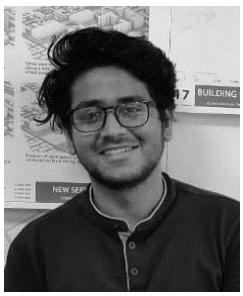


ARYAN ARORA
B.Arch. (5th Year, Amity Univ.)
Innovation

Team Approach

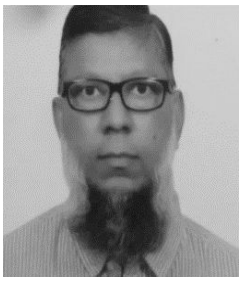
The SDI's 10 contests have been taken into consideration, and an integrated strategy has been used. A contest has been allocated to each participant based on their academic qualifications and inherent skills. Our team has been subdivided into simulation, calculation, modelling, and presentation groups, with each team member contributing to the architectural design.

Our goal is to adhere to an evidence-based design process in which design choices are supported by analysis of the available data. We have been setting up regular meetings with the faculty and the team members, both in person and online.

Background of the lead institution :

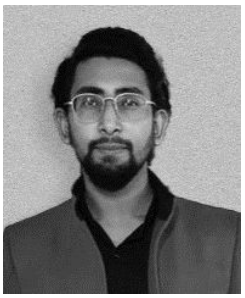
Jamia MIllia Islamia is the 3rd top University in the country as per the NIRF 2022 rankings. Complementing its mission i.e 'Social concern & Innovation', its Faculty of Architecture & Ekistics has a vision to train the students to create Architecture with soul.

Faculty Lead

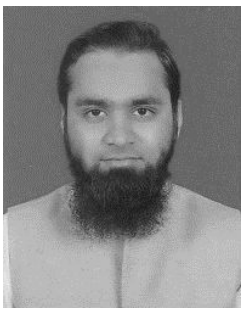


Ar. Mohd Firoz Anwar- Associate Professor
Architecture Faculty at FAE JMI, New Delhi. Specialized in Architecture, Low Cost Construction Techniques and Nanotechnology in Architecture. He did his B Arch with Honours from AMU and M Arch (First Position) from IIT Roorkee. He has more than 23 years of experience in academics.

Faculty Advisors



Fahad Bin Khurshid- Assistant Professor
Architecture Faculty at FAE JMI, Specialized in Earthquake Engineering, Pursuing PhD from Department of Civil Engineering, Faculty of Engineering & Technology, JMI.



Nabeel Ahmed Khan- Contractual Faculty
Engineering Faculty at FET JMI, New Delhi. Specialized in Structural Engineering, He did his B.Tech from JMI and MTech in Structural Dynamics from IIT Roorkee, with a PhD in Structural Engineering from IIT Delhi.

Industry Partner

Abdul Azeem
Product Engineer

Company- Employwise

powered by EmployWise

RicronPanels

Project name: Aashiyan

Project partner: Larsen & Toubro Construction

Key individuals involved: *Name of the project manager requested to be kept confidential*
Planning Engineer: Padmadip Joshi L&T WET

Larsen & Toubro (L&T) is a major Indian technology, engineering, construction, manufacturing, and financial services firm with international operations. Their main line of business is the construction of various structures such as commercial, industrial, transportation, heavy civil infrastructure, power transmission and distribution, and water & effluent treatment plants.

Project Background

Water resources in South Gujarat are limited, which has an impact on its overall growth. The goal of the project is to use the extra water at the Ukai reservoir in the Tapi District to irrigate the command area's (Narmada and Surat District's) water supply via an underground pipeline distribution system. For the 16919 Hac. Command area, an underground distribution network is suggested for field-to-field irrigation.

Figure 1: Workers engaged in construction

Brief Description Of The Project:

Engineering, Procurement and Construction (EPC) aims for Construction of Pumping Station - 4 Nos. at various locations and transmission of 500 cusec of water by supplying and laying M.S. pipeline of various dia including designing, providing, lowering and laying underground pipeline distribution network in command area with allied works, etc. with O&M of 10 years.

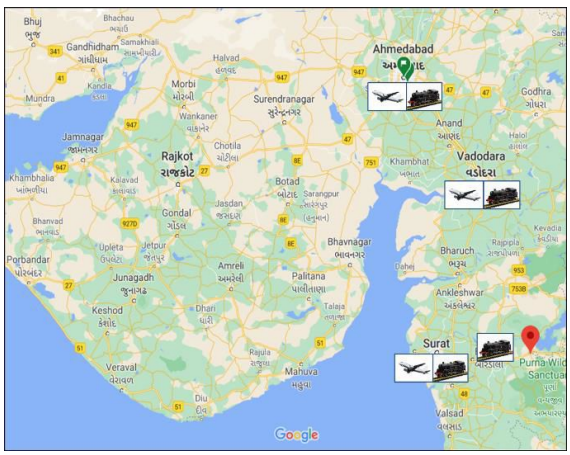


Figure 2- Site Accessibility

Location: The proposed site is near Ukai Village, Songadh, Tapi District, Gujarat.

Climate zone: Hot and dry climate zone

Connectivity: The site is 330 km from Ahmedabad, 220km from Vadodara and 100km from Surat via road and 20km from Vyara Railway Station with the nearest airports of Ahmedabad, Surat and Vadodara.

Mode of transport to the site: By walk, mini bus, or car

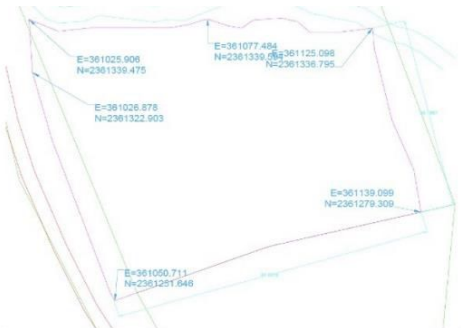


Figure 3- Site Boundaries

Ownership: The land is owned by regional farmers and is handed over to L&T on lease from 23rd Oct 2020 to 22nd Oct 2030.

Status of project: The site houses 2 labour camps PS2 & PS3, each with 90 workers currently (Maximum Capacity = 160 each).

Site Area: 8000 sqm

Permissible built up area: 18000 sqm

Permissible ground coverage: 6000 sqm

Estimated built up area: 3323 sqm

EPI Target: 29 kWh/m^2/year

Estimate of on-site renewable energy generation potential using solar panels = 8628 kWh/m^2/year

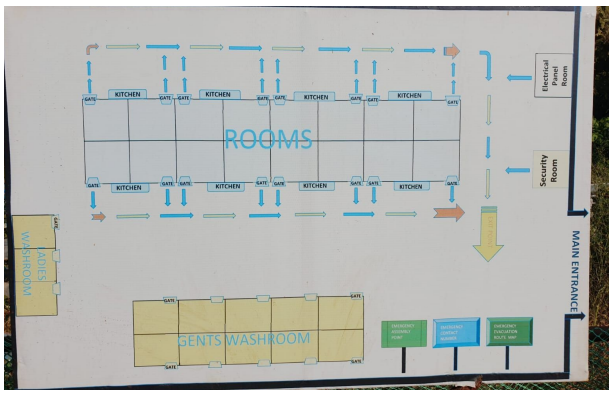


Figure 4- Layout of the existing workmen camp

Worker's Profile	Skilled, Semi Skilled & Unskilled Laborers, migrant workers.
Background	Civil, MEP, Specialized agencies
No. of Workers	Avg. 240 workers
	Max capacity reached in the period between December to May
Male Female ratio	07:01
Hours of operation	The workers leave the camp at 8 am and return at 8 pm

Table 1:- Workers Profile

Socio Economic context:

The camp comprises of both migrant and regional workers, majority of which make up to 80% of the workforce belonging to states of UP and Bihar, while the rest 20% belong to various parts of Gujarat.
Electricity is made available through DG sets kept on site.
Water is supplied through a borewell, which can be stored in storage tank.

Figure 5: Workers engaged in construction

Existing challenges:

The site is located in a remote location with poor connectivity to its surroundings.
Situated with forest land around it, transportation and access are a key challenge to site.
Human movement and machine operation scares the wildlife and risks trespassing of wild animals on site.

Figure 6:Camp toilets close to forested area

Regional resources:

The site has abundance in bamboo, stone and wood as it's regional materials.
Lying in close proximity to stone mines of Songadh, it provides good availability of stones for construction.
Crushed stones hold potential of being used as aggregates whereas stone dust could be used as setting bed for stone pavers.

Figure 7 :Mining work at Songadh

ENERGY PERFORMANCE

GOAL: EPI target 26 kwh/m2/year

ACHIEVEMENTS:

- Achieved Epi= 13.10 Kwh/Sqm-Year
- Total annual energy savings= 1,17,187 kwh

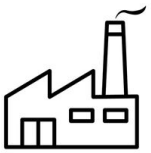
WATER PERFORMANCE

GOAL: Becoming Net Positive in Water Consumption

ACHIEVEMENTS:

- Efficient toilets like Dual flush toilets should be used which has 2 flush- 6litrs/flush and 3litre/ flush
- Low water use urinals consume upto 0.8litres /flush while the conventional use upto 4 litres/flush

EMBODIED CARBON



GOAL: To Achieve minimum or less Carbon emission i.e. 150kgCO2e/m2 on completion of On-site construction workers housing.

ACHIEVEMENTS:

- Roof, flooring and walls made of ricron panels which have low carbon emission factor of 0.56 kg.CO2.e/m2.
- All the materials sources lie within the range of 150 km lowering the impact of carbon emission caused by transportation.

RESILIENCE

GOAL: To make structure withstand seismic and cyclonic forces. To make it resistant to fire and extreme weather conditions.

ACHIEVEMENTS:

- Using Mild steel as a structure framework to withstand lateral shockwaves of earthquake forces and also resist wind up to 123 mph.
- Using ricron eco roof sheets for roofing to resist adverse weather condition and also to resist fire.
- By providing on site medical services for emergency, reserves of water, food and sanitation and power generators and batteries in case of collapse of power transmission.

ENGINEERING AND OPERATIONS

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GOAL: To minimise material use and maximise structural efficiency that gives optimum cost. Devise an operational plan that ensures accurate function of units

ACHIEVEMENTS:

- using ricron panel made up of waste plastic in wall and roof.
- by using steel frame and concrete foundation.
- Using HSFG bolt system ensures accurate function of units which can help streamline the construction process.

ARCHITECTURAL DESIGN

GOAL: To design spaces that fulfill the needs of the users and provide comfort in terms of ventilation, heat,etc.

ACHIEVEMENTS:

- By providing courtyard within the community space that will regulate ventilation and also act as a social interactive space.
- By providing fenestration on the shaded side so that it can utilise proper air and cut heat waves.

VALUE PROPOSITION

GOAL:To provide a hygienic and comfortable living unit for users, with a modular and movable solution that eliminates waste with net zero energy and net zero water applicable pan India

STRATEGIES:

- Using of biogas plant to eliminate waste generated from site
- Replacing use of high embodied carbon material with low or negative carbon embodied material to reduce carbon footprint.

AFFORDABILITY

GOALS:

- **Reducing building cost and time by the use of ricron panels and simple joinery rather than traditional porta cabins.**
- **Ensuring negligible Maintenance requirements.**
- **Minimizing transportation costs.**

ACHIEVEMENT:

- Lesser overall life cycle cost because of careful selection of materials and fixtures
- Reduced on-site assembling and disassembling time.

INNOVATION

GOAL: Site-independent dwelling modules can be scalable across most sites and climatic zones

ACHIEVEMENTS:

- Designing a mobile application for contractors/ construction companies showing options for site layout while maintaining net zero and comfort factors.

HEALTH AND WELLBEING

GOAL: To achieve maximum no of occupied hours/operative hours as comfort hours and better quality of life

ACHIEVEMENTS:

- Achieved 65 percent of occupied hrs as comfort hrs
- After running dynamic energy, comfort hr temp for 80% residents ranges from 23.6 to 31.8 degree celcius

AWARENESS

GOAL: Raising various educational, operational safety and health care related awareness among the users with the help of NGOs and health drives.

ACHIEVEMENT : Lesser on site accidents and more safety/first aid related awareness whilst also provision of a safe learning space for their children.

1. ENERGY PERFORMANCE

ENVELOPE OPTIMIZATION

- **BENCHMARK EPI= 26 KWH/SQM-YEAR**
- **ACHIEVED EPI= 13.10 KWH/SQM-YEAR**

PASSIVE STRATEGIES-

- Low thermal transmittance, low embodied carbon and high insulation materials used to reduce solar heat gain through building.
- Natural Ventilation
- Controlled daylighting with minimal glare

ACTIVE STRATEGY-

- Solar PV panels to generate on-site renewable energy.

Ricron panels are made from plastic & aluminium composite, corrugated roof sheet and is cost effective, long lasting, eco-friendly and weatherproof option

Ricron Panel cabins are easy to construct end to end solutions using high strength, waterproof, fire rated, anti-bacterial, anti-fungal panels to construct portable cabins. It is long lasting and eco friendly material.

Ricron Eco-roof sheets are waterproof, rust proof and termite proof which substantially increases the life of the roof. The consistency of the composite leads to very high quality and strength. Ricron Eco-roof sheets are light weight high tensile sheet which lowers transportation issues and keeps your roofing maintenance free.

Figure 8-ricron panels

SOLAR ENERGY GENERATION

The site receives an average solar irradiance of 5.81kWh/sqm per day which promises a **positive solar potential**. The solar panels are placed on the rooftop to meet the demands of energy requirements. Solar rooftop calculator was used to calculate the solar energy generated on the site.

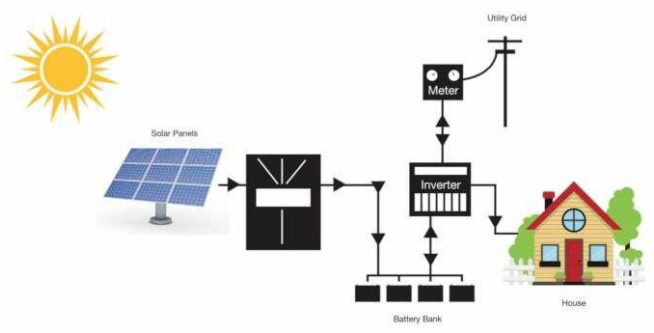


Figure 9- schematic working diagram of PV panels

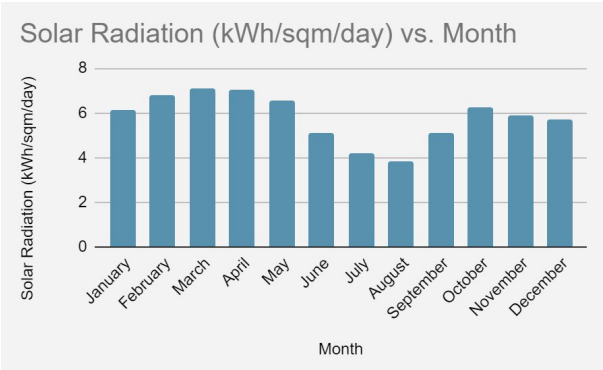


Figure 10- monthly solar radiation in kwh/sqm/day

Average solar irradiation in GUJARAT state is 1266.52 W / sq.m
1kWp solar rooftop plant will generate on an average over the year 5.0 kWh of electricity per day (considering 5.5 sunshine hours)

1. Size of Power Plant	
Feasible Plant size as per your Roof Top Area :	97.0kW
2. Cost of the Plant :	
MNRE current Benchmark Cost (without GST) :	Rs. 38236 Rs. / kW
View Benchmark Cost List	
Without subsidy (Based on current MNRE benchmark without GST) :	Rs. 3708892
With subsidy 0 (Based on current MNRE benchmark without GST) :	Rs. 3708892
3. Total Electricity Generation from Solar Plant :	
Annual :	145500kWh
Life-Time (25 years):	3637500kWh
4) Financial Savings :	
a) Tariff @ Rs.4.57/ kWh (for top slab of traffic) - No increase assumed over 25 years :	
Monthly :	Rs. 55411
Annually :	Rs. 664935
Life-Time (25 years) :	Rs. 16623375

Carbon dioxide emissions mitigated is	2983 tonnes.
This installation will be equivalent to planting	4772 Teak trees over the life time. (Data from IISc)

Month	Solar Radiation (kWh/sqm/day)
January	6.15
February	6.78
March	7.08
April	7.01
May	6.57
June	5.11
July	4.2
August	3.86
September	5.13
October	6.25
November	5.87
December	5.72
ANNUAL	5.81

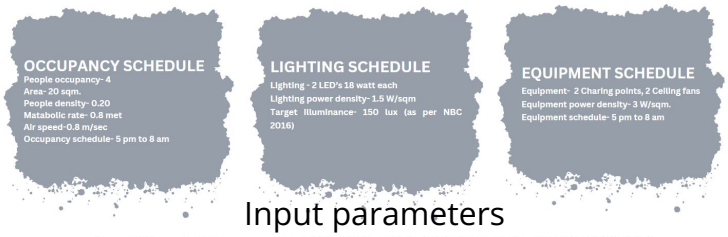
Table 1- monthly solar radiation in kwh/sqm/day

Total electricity generation from the solar plant= 1,45,500 kwh
Installed capacity= 97 kw
Total annual energy savings= 1,17,187 kwh

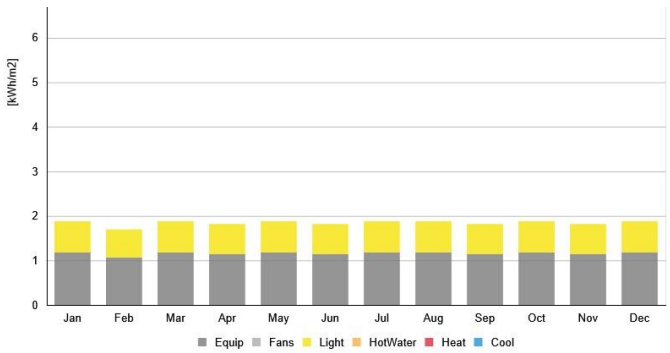
EPI CALCULATION

The simulation was done on climate studio using the input parameters shown below and manual epi calculations were also done.

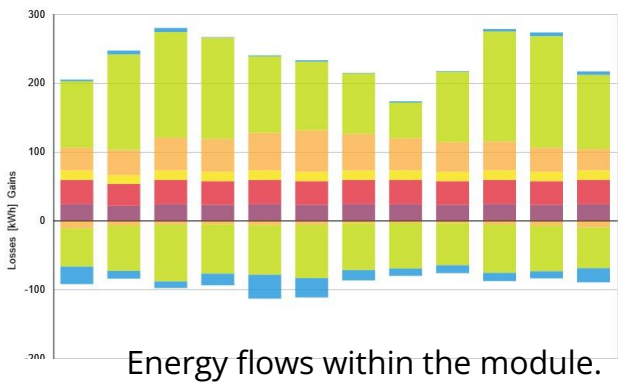
Simulated energy performance



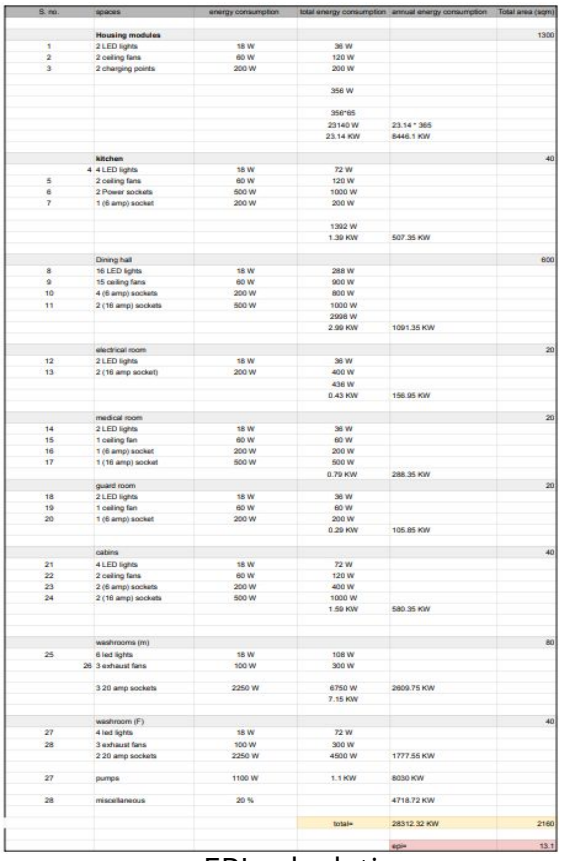
Input parameters



Energy used per month



Energy flows within the module.



S. no.	spaces	energy consumption	total energy consumption	annual energy consumption	Total area (sqm)
	Housing modules				1300
1	2 LED lights	18 W	36 W		
2	2 ceiling fans	60 W	120 W		
3	2 charging points	200 W	200 W		
			356 W		
			356*65		
			23140 W	23.14 * 365	
			23.14 KW	8446.1 KW	
	kitchen				40
4	4 LED lights	18 W	72 W		
5	2 ceiling fans	60 W	120 W		
6	2 Power sockets	500 W	1000 W		
7	1 (6 amp) socket	200 W	200 W		
			1392 W		
			1.39 KW	507.35 KW	
	Dining hall				600
8	16 LED lights	18 W	288 W		
9	15 ceiling fans	60 W	900 W		
10	4 (6 amp) sockets	200 W	800 W		
11	2 (16 amp) sockets	500 W	1000 W		
			2988 W		
			2.99 KW	1091.35 KW	
	electrical room				20
12	2 LED lights	18 W	36 W		
13	2 (16 amp socket)	200 W	400 W		
			436 W		
			0.43 KW	156.95 KW	
	medical room				20
14	2 LED lights	18 W	36 W		
15	1 ceiling fan	60 W	60 W		
16	1 (6 amp) socket	200 W	200 W		
17	1 (16 amp) socket	500 W	500 W		
			0.79 KW	288.35 KW	
	guard room				20
18	2 LED lights	18 W	36 W		
19	1 ceiling fan	60 W	60 W		
20	1 (6 amp) socket	200 W	200 W		
			0.29 KW	105.85 KW	
	cabins				40
21	4 LED lights	18 W	72 W		
22	2 ceiling fans	60 W	120 W		
23	2 (6 amp) sockets	200 W	400 W		
24	2 (16 amp) sockets	500 W	1000 W		
			1.59 KW	580.35 KW	
	washrooms (m)				80
25	6 led lights	18 W	108 W		
26	3 exhaust fans	100 W	300 W		
	3 20 amp sockets	2250 W	6750 W	2809.75 KW	
			7.15 KW		
	washroom (F)				40
27	4 led lights	18 W	72 W		
28	3 exhaust fans	100 W	300 W		
	2 20 amp sockets	2250 W	4500 W	1777.55 KW	
27	pumps	1100 W	1.1 KW	8030 KW	
28	miscellaneous	20 %		4718.72 KW	
			total=	28312.32 KW	2160
				epi=	13.1

EPI calculation

WATER PERFORMANCE

As per National Building Code 2016, the baseline water demand where amenities are required is 135 LPD per capita, for residentials which can be reduced by upto 60%, i.e 55 LPD By the use of efficient water fixtures and other behavioural measures. So according to the domestic water usage pattern per day the water consumption per day and annual consumption is shown in the table below-

	Per capita daily consumption	No.of occupants	Daily water consumption	Yearly water consumption	Grey water filter efficiency
BASE CASE	135	240	32,400	1,18,26,000	75%
DESIGNED CASE	55	240	13,200	48,18,000	75%

Table2 : Annual water consumption

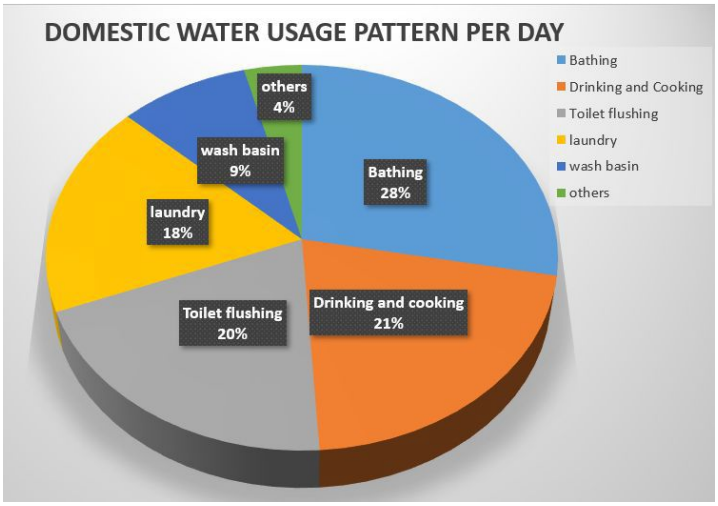


Figure 11 : Pie chart showing Domestic water usage per day

USE	WATER CONSUMPTION PER DAY (PER CAPITA)	ANNUAL CONSUMPTION (PER CAPITA)
Drinking and Cooking	11.5L	4197.5L
Bathing	15.4L	5621L
Laundry	9.9L	3613.5L
Flushing	11L	4015L
Wash basin	4.95L	1806.75L
Others	2.2L	803L

Table 3: Table showing annual water consumption (per capita)

WATER SAVING MEASURES-

- **Water Saving Aerators** are one of the best innovative water saving solutions Whether it is a washbasin, bath shower, sink taps or faucet.It has 50 % air and 50% water.
- Efficient toilets like **Dual flush toilets should be used which has 2 flush- 6litrs/flush and 3litre/ flush**
- Low water use urinals consume upto **0.8litres /flush** while the conventional use upto 4 litres/flush
- Sensor taps should be used to automatically shut off taps to avoid water wastage.

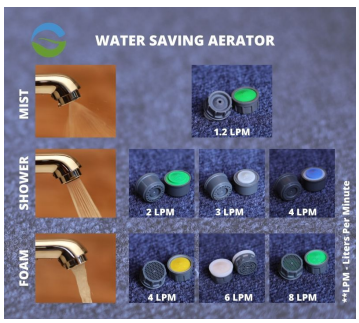


Figure 12 : Water Saving Aerator

8 LPF reduced to 3 LPF

8 LPF reduced to 4 LPF

Grey water treatment

It is projected that the building generates **9.4 KL of grey water and 3.8KL of black water every day**. The grey water is recycled, filtered and reused for flushing, irrigation, and PV maintenance.The greywater is stored in a tank and is filtered through the root zone treatment method. Root zone treatment is an engineered method of purifying wastewater as it passes through the artificially constructed wetland area.The pollutants are removed by various physical, chemical and biogeochemical processes like sedimentation, absorption, and nitrification as well as through uptake by wetland plants.

The extra treated wastewater is used to recharge the groundwater.

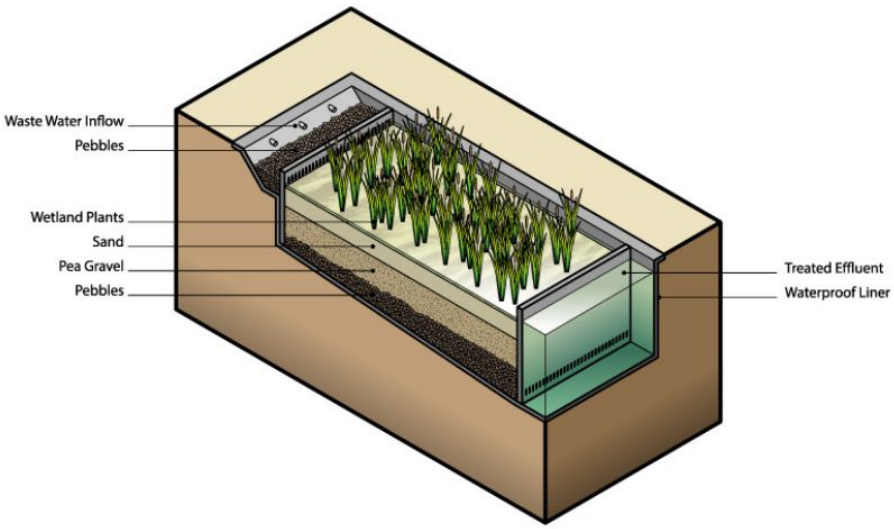


Figure 13 :Root zone treatment for grey water treatment

Rainwater harvesting surfaces	Area m^2	Runoff coeffecient	Effective catchment area m^2
Roof Surfaces	2685	0.85	2282.25
Hardscape area	884	0.70	618.8
Softscape areas	4431	0.30	1329.3
Other			0
Total Effective catchment area			**4230.35**

Table 4: Rainwater harvesting calculations

End Use	Percent use	Use in LPD	Greywater in %	Blackwater in %
Bathing	28%	3696	100	
Washing	20%	2640	100	
Cleaning house	8%	1056	100	
Washing Utensils	14%	1848	100	
Others	2%	264	50	50
Drinking	6%	792		100
Cooking	5%	660		100
Toilet Flushing	17%	2244		100
Total		**13200**	**9,372**	**3,828**

Table 5: greywater and blackwater calculations

		Consumption		Water sources				
Month	Days in month	Domestic Use (L)	Total Consumption (L)	Effective rain (mm)	Rainwater	Generated Greywater (L)	Filtered Greywater (L)	Blackwater (L)
Jul	31	4,09,200	4,09,200	409195	1745865	2,90,532	2,17,899	1,18,668
Aug	31	4,09,200	4,09,200	409195	1245415	2,90,532	2,17,899	1,18,668
Sep	30	3,96,000	3,96,000	395995	785576	2,81,160	2,10,870	1,14,840
Oct	31	4,09,200	4,09,200	409195	93914	2,90,532	2,17,899	1,18,668
Nov	30	3,96,000	3,96,000	395995	33843	2,81,160	2,10,870	1,14,840
Dec	31	4,09,200	4,09,200	409195	0	2,90,532	2,17,899	1,18,668
Jan	31	4,09,200	4,09,200	409195	0	2,90,532	2,17,899	1,18,668
Feb	28	3,72,900	3,72,900	372895	0	2,64,759	1,98,569	1,08,141
Mar	31	4,09,200	4,09,200	409195	0	2,90,532	2,17,899	1,18,668
Apr	30	3,96,000	3,96,000	395995	0	2,81,160	2,10,870	1,14,840
May	31	4,09,200	4,09,200	409195	9730	2,90,532	2,17,899	1,18,668
Jun	30	3,96,000	3,96,000	395995	1033475	2,81,160	2,10,870	1,14,840
Total		48,21,300	4821300		4947817	34,23,123	25,67,342	13,98,177

Table 6: water consumption and sources

RAINFALL HARVESTING CALCULATIONS

Total Effective catchment area (m^2) = 4230.35 m^2
Total Rainfall harvested in a year (litres) = 49,47,817 litres

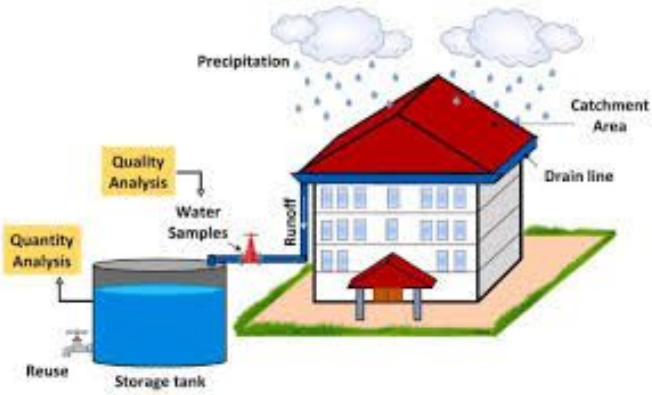


Figure 14 : Rainwater harvesting

• In this area, rain water harvesting structure associated with storage tank can be constructed for domestic purpose since its the most feasible.
Rainy FL-500 filtration system is used to remove the dirt and impurities with more than 90% efficiency, is later deposited in underground water tank (UGT)
• Existing and abandoned dug wells may be utilized as recharge structure after cleaning and desilting the same.This is a cost effective method to enhance the availability of ground water and improve the ground water quality.Since the rain fall in this part of the State is generally high, suitable measures to augment the ground water resource may be adopted.Such measures could be contour bunding, gully plugging,etc.

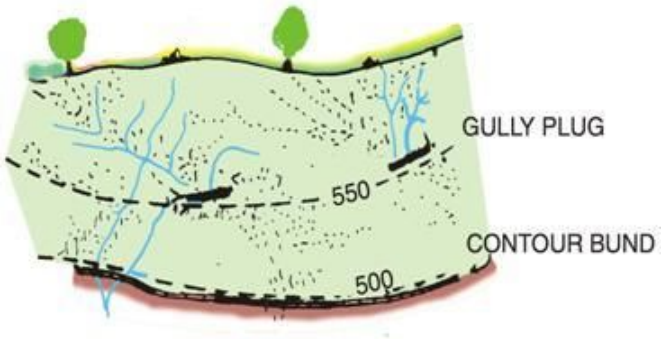


Figure 15 :Gully plug and contour bund for recharging ground water

TOTAL WATER REQUIREMENT (KL/year)	4831.3 KL/YR
HARVESTED RAINWATER (KL/year)	4947.8 KL/YR
RECYCLED GREY WATER (KL/year)	2567.3 KL/YR

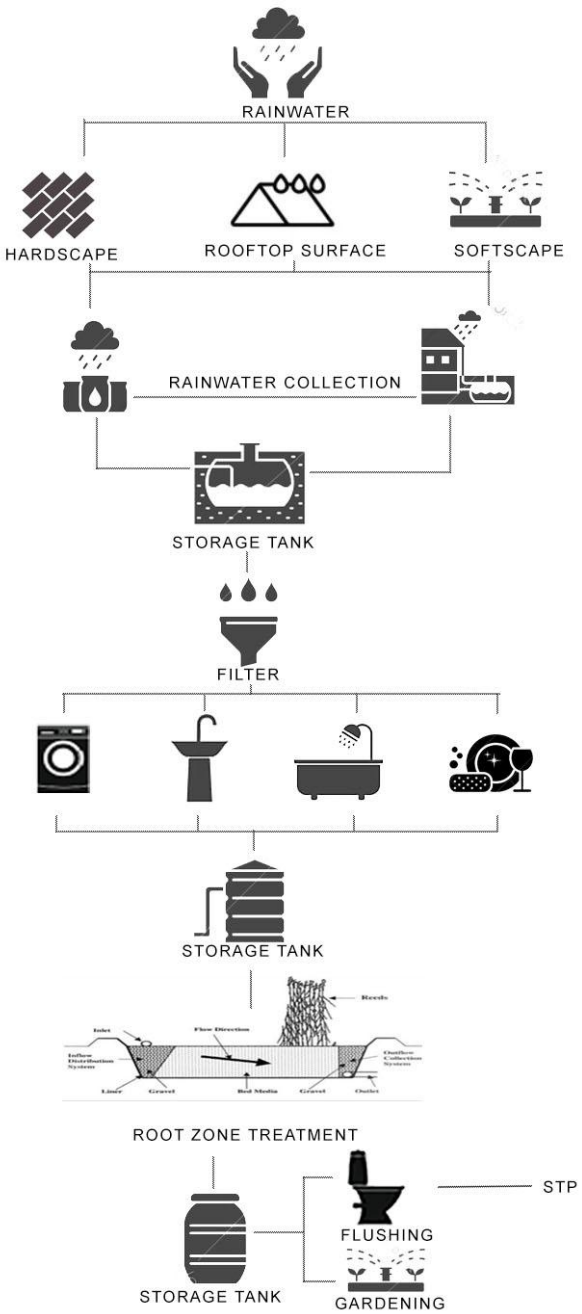


Figure 16 :Water cycle

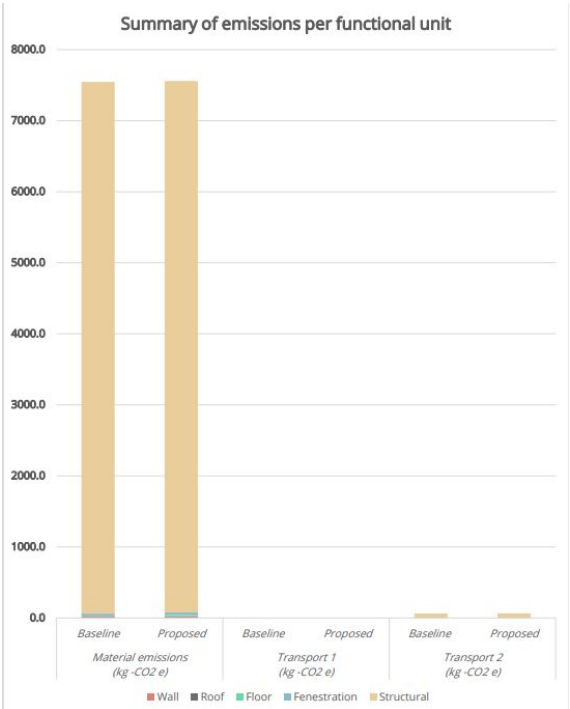
3. EMBODIED CARBON

System Type	Baseline			
	Material emissions ($kg\text{-}CO_2e$)	Transport 1 ($kg\text{-}CO_2e$)	Transport 2 ($kg\text{-}CO_2e$)	Total ($kg\text{-}CO_2e$)
Wall	19.2	0.0	0.4	19.6
Roof	3.0	0.0	0.1	3.0
Floor	2.5	0.0	0.1	2.5
Fenestration	35.7	0.0	0.4	36.1
Structural	7485.5	0.0	63.3	7548.7
			Grand Total emissions per functional unit ($kg\text{-}CO_2e$)	7610.0

Table 7: chart for Total emission (Baseline)

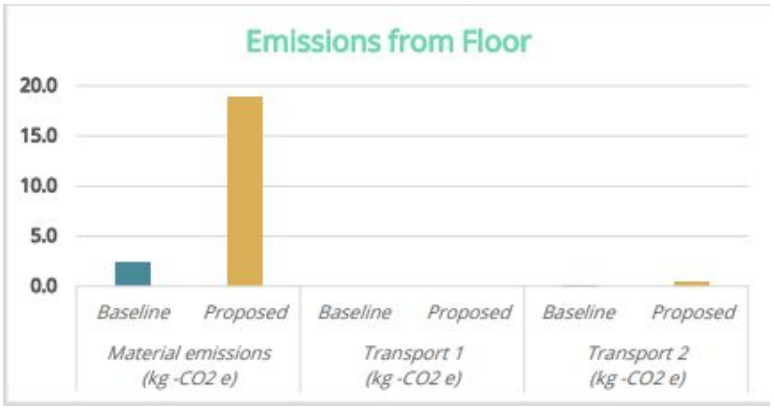
Proposed			
Material emissions ($kg\text{-}CO_2e$)	Transport 1 ($kg\text{-}CO_2e$)	Transport 2 ($kg\text{-}CO_2e$)	Total ($kg\text{-}CO_2e$)
19.2	0.0	0.4	19.6
3.0	0.0	0.1	3.0
19.0	0.0	0.5	19.5
35.7	0.0	0.4	36.1
7482.4	0.0	63.3	7545.7
		Grand Total emissions per functional unit ($kg\text{-}CO_2e$)	7623.9

Table 8: Chart for Total emission (Proposed)

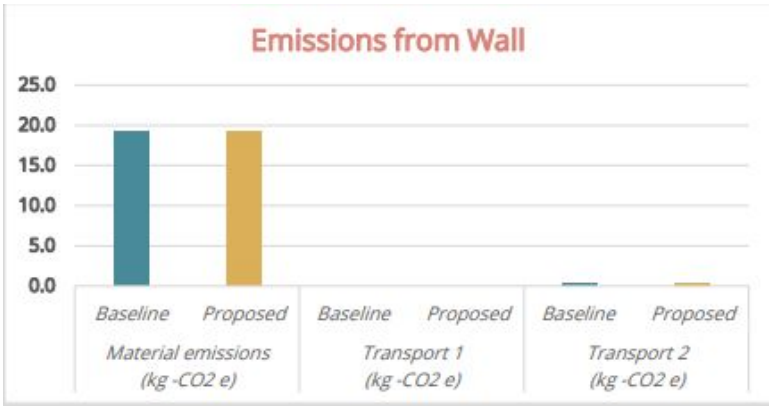


Graph: summary of emission per functional unit

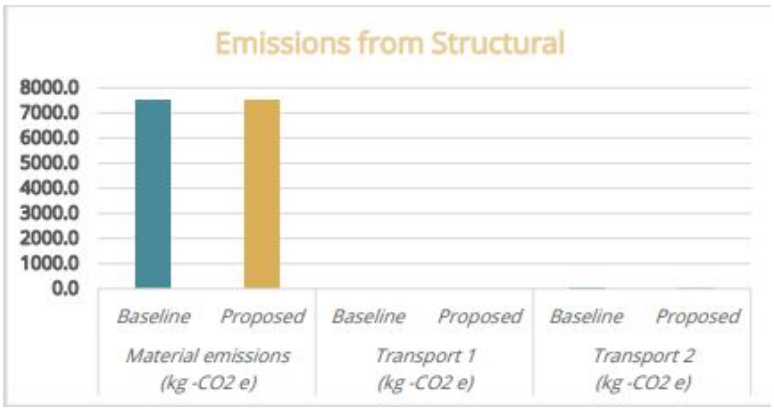
3. EMBODIED CARBON



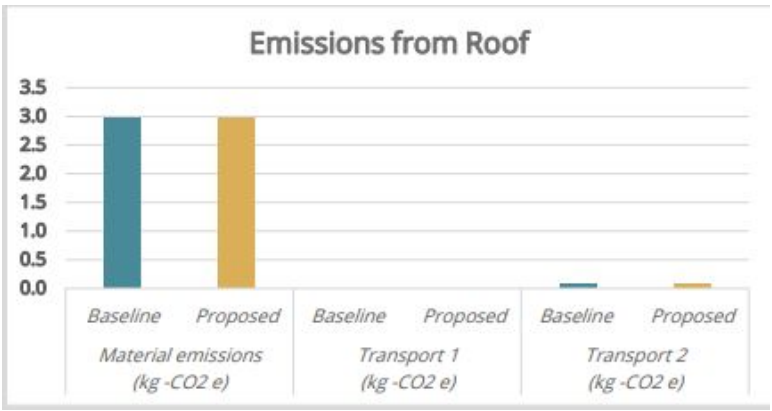
Graph: Emission from floor



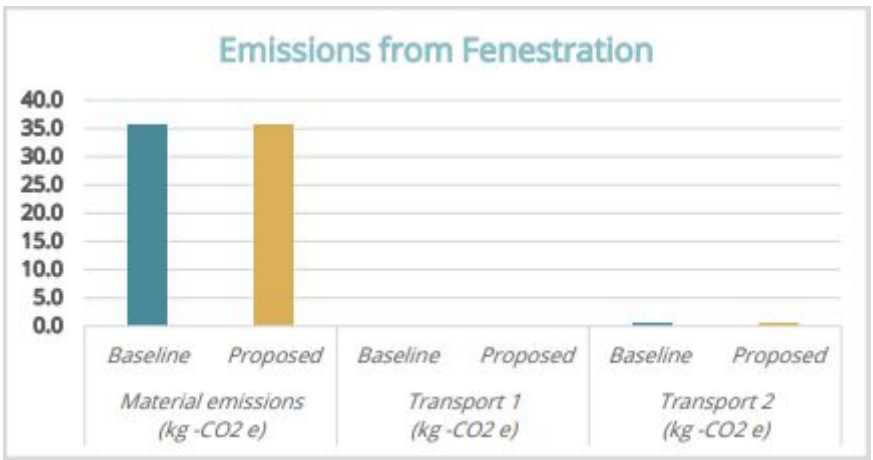
Graph: Emission from wall



Graph: Emission from structural member



Graph: Emission from roof



Graph: Emission from fenestration

4. RESILIENCE

According to vulnerability Atlas of india, the site lies under following hazard zones:

- Moderate Damage Risk (Zone III) of earthquake with magnitude of 5-5.9
- Moderate Damage Risk of Wind hazard (Zone B) with Vb value of 39 m/s.

Vb= Basic wind speed

EARTHQUAKE	CYCLONES	FIRE HAZARD	RISKS & DAMAGES	SOLUTIONS TO REDUCE VULNERABILTY	PREPAREDNESS
			Structure system may collapse or mild damage to the structure	Using mild steel as a structure framework because of its high strength, Ductility and light weight properties. To withstand lateral shock waves of earthquake forces.	On site open areas for evacuation and medical relief camps.
			Catastrophic failure (Foundations, steel frames, etc.)	Steel as a structure member can withstand wind up to 123 mph. Proper connections between steel members of a module using nut and bolt.	Provision of warning alert system for evacuation.
			Component failure (Roof sheeting or tiles, windows and doors, etc.)	The roof is installed using technique of framing, fastening and sealing. Recycled plastic waste panels are provided as roofing having compressive strength 39.12 N/sq.mm, yield strength 6.3 N/sq.mm and high durability.	Trees around houses as a permeable barriers.
			Structural damage	Use of Recycled plastic waste panels for walls which provides resistance from fire as it can take heat up to 105 deg. Celsius.	Provision of fire extinguishers and fire hose.
			Immediate help may not be available		Provision of First-aid and medical facilities. Availability of Ambulance or Vans to ensure the accessibility to the nearest hospitals.
			Shortage of resources		On site reservoirs and storages of food, Clothes and sanitation.
			Collapse of power transmission.		On site power generator, reserves and batteries.
			Communication Breakdown		provision of satellite phone and Amateur radio services (HAM)
			Temporary failure of transportation services.		On site vehicles and storages of Foods and other basic necessities.
			Disruption of water supply.		On site water reserves and provision of water harvesting system.

Table 9:- Resilience

Passive design strategies have been adopted to make it heat and weather resilient design-

- By providing orientation of residential blocks on north direction making it less heated in summers.
- By providing shading through the extended roof
- By the placement of Doors and windows in opposite side providing ventilation.
- By using heat resilient material.

Resilience metrics of Passive performance

- **How many hours in a year can the building provide comfort without using mechanical devices?**
  The designed modules can work to provide thermal comfort for 3554 hours a year with passive performance only,i.e., without any mechanical devices.

- **How many days of Autonomy for critical functions can the building provide?**

❏ Energy includes lights and fans can run for **31 hours (1.7 days)** during disaster situation as solar panels provide 1,45,500 Kwh a year to run the whole sights with an average of 1.7 days backup in summers. During winters, it can give more backup since fans will not be operated.

❏ To sustain the water demands, rain water harvesting and water filtration plants are designed to store water which can be used for **29 hours (1.5 days)** in disaster situations.

❏ Food storage areas are provided to sustain food supply.

Disaster Risk management & Recovery plan

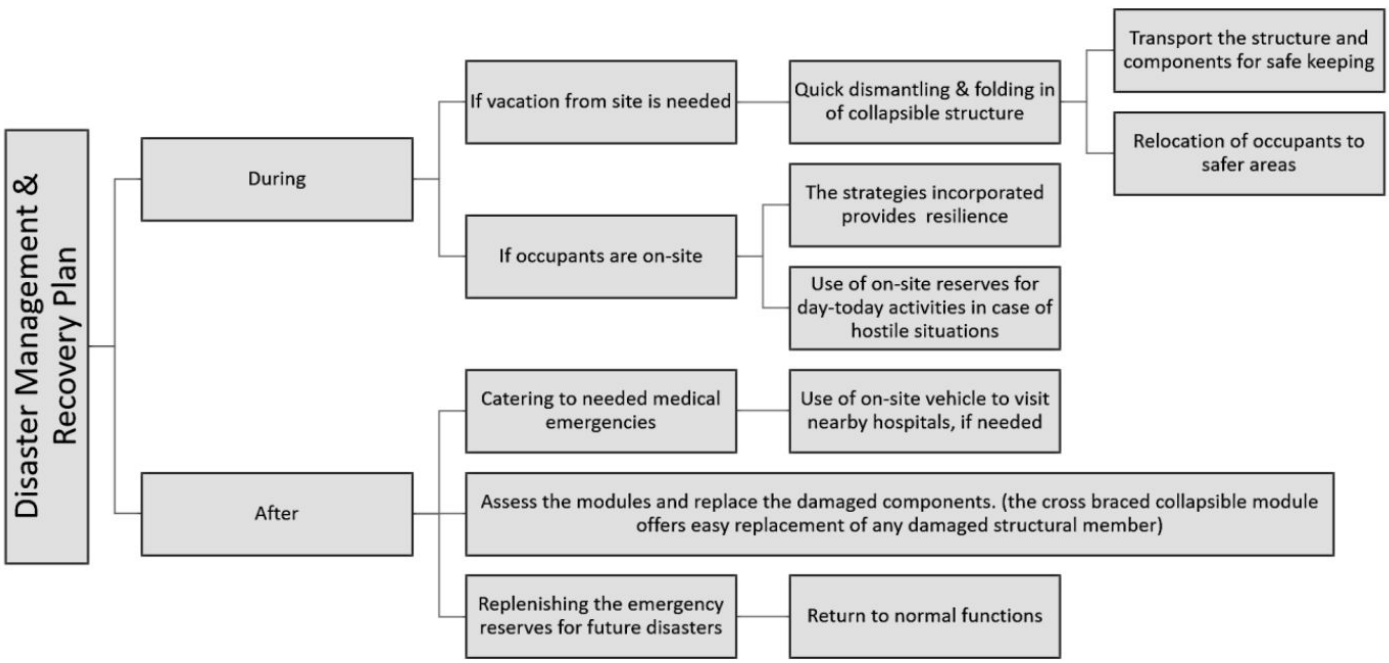


Table 10 : Disaster risk management and Recovery plan

5. ENGINEERING AND OPERATIONS

FOUNDATION

Engineering design: The foundation design should consider the load capacity of the column, the soil bearing capacity, and the structural requirements for stability and safety. The dimensions of the foundation can be determined by calculating the required bearing area for the column load and soil pressure.
Foundation construction: The foundation can be constructed using standard concrete mix and reinforcement as per the design specifications. The dimensions of the foundation can be 250mm x 250mm x 500mm. The foundation should be cured for the recommended period before proceeding to the next step.

Steel base plate installation: A steel base plate can be installed on top of the foundation using non-shrinking grout to ensure proper adhesion and alignment. The base plate dimensions should be sufficient to distribute the column load uniformly over the foundation.

Anchor bolt installation: Anchor bolts can be installed through the base plate and into the foundation. The bolts should be designed to resist the column loads and other lateral forces that may be applied to the column.

Column installation: The RHS steel column can be placed onto the base plate and bolted to the anchor bolts using nuts and washers. The column should be aligned properly and leveled using leveling nuts before tightening the bolts to the recommended torque.

Non-shrinking grout installation: Non-shrinking grout can be poured into the gap between the column and the foundation to ensure proper transfer of the column loads to the foundation. The grout should be applied in layers and allowed to cure according to the manufacturer's instructions.

Inspection and testing: The foundation and column connection should be inspected and tested to ensure that it meets the design requirements and specifications. This may include checking for proper alignment, levelness, and torque of the bolts, as well as load testing the column to ensure that it can resist the design loads.

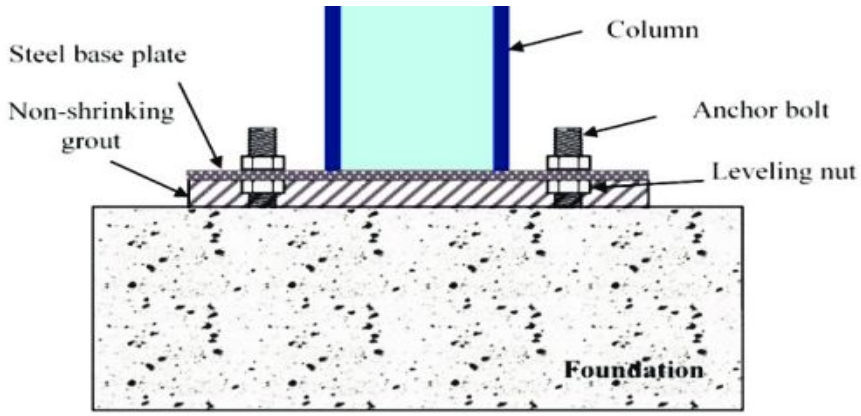


Figure 19: Foundation Detail

5. ENGINEERING AND OPERATIONS

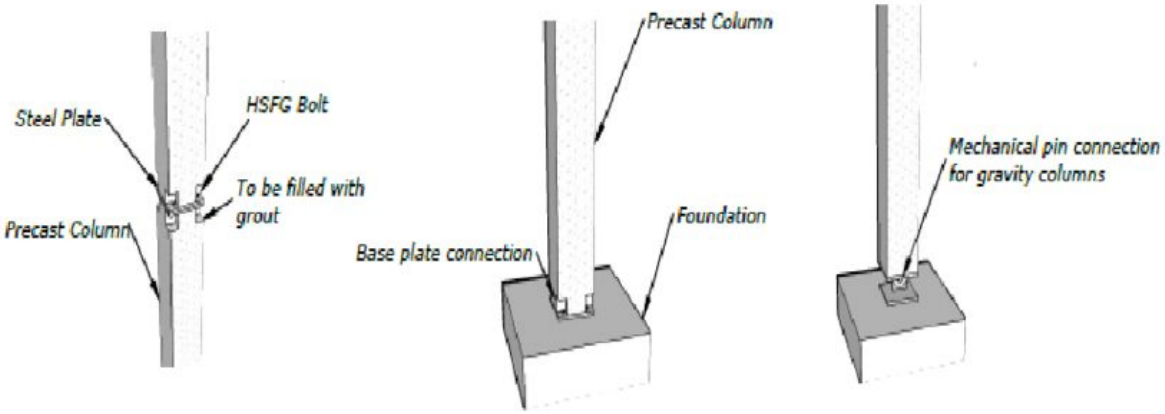


Figure 17 : joinery details of column with foundation

BRACING:

1. Engineering design: The design of the metal bracing should consider the load capacity, span, and spacing of the braces, as well as the overall structural requirements for stability and safety. The dimensions and material of the braces can be determined by calculating the required strength and stiffness for the intended loads and spans.

3. Bracing fabrication: The metal braces can be fabricated using standard cutting, drilling, and welding techniques. The braces can be cut to the desired lengths, drilled for bolt connections or welding, and welded to form the required shapes and configurations. The welding should be performed according to standard welding procedures to ensure proper strength and integrity.

4. Bracing installation: The metal braces can be installed by connecting them to the ricron fiber wall using bolts, depending on the design requirements. The braces can be secured to the wall at appropriate intervals to provide the required support and stability.

5. Inspection and testing: The metal braces and carbon fiber wall should be inspected and tested to ensure that they meet the design requirements and specifications. This may include checking for proper alignment, levelness, and squareness of the braces, as well as load testing the wall to ensure that it can resist the design loads.

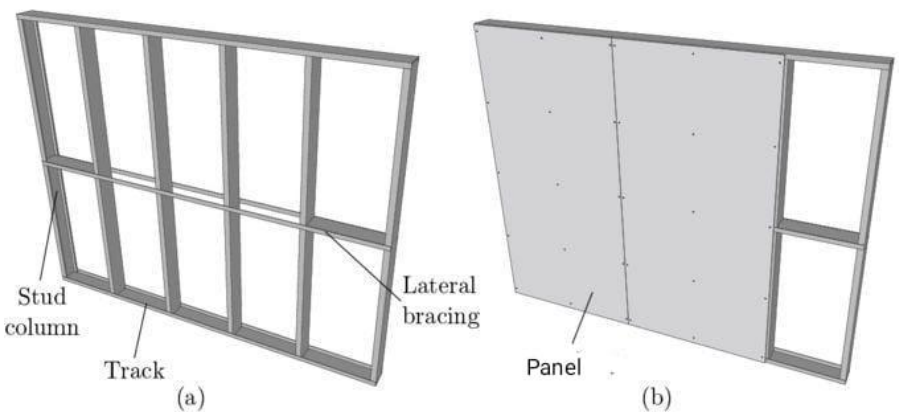


Figure 18: Panel Details

COLUMN & BEAM FRAMEWORK:

1. Engineering design: The design of the framework should consider the load capacity, span, and spacing of the beams and columns, as well as the overall structural requirements for stability and safety. The dimensions of the RHS beams and columns can be determined by calculating the required strength and stiffness for the intended loads and spans.

1. Load requirements: The required dimensions of the RHS beams and columns depend on the loads they are expected to carry. This includes the weight of the structure itself, as well as any external loads such as people, equipment, wind, and snow.
2. Span requirements: The span of the beam or column is the distance between the two supports. The longer the span, the larger the required cross-sectional area of the RHS section.
3. Material properties: The properties of the material used for the RHS sections, such as the yield strength and elastic modulus, will affect the required dimensions.
4. Stiffness requirements: The required dimensions of the RHS sections will also depend on the desired level of stiffness, which affects the deflection and stability of the structure.

2. Material selection: Mild steel is a common material for RHS beams and columns due to its high strength, durability, and affordability. The dimensions of the RHS beams and columns can be 50mm x 50mm x 2mm, which are suitable for most light to medium-duty applications.

3. Framework fabrication: The beams and columns can be cut to the desired lengths, drilled for bolt connections to form the required framework.

4. Assembly and installation: The framework can be assembled by connecting the beams and columns using bolts or welding, depending on the design requirements.
5. Inspection and testing: The framework should be inspected and tested to ensure that it meets the design requirements and specifications. This may include checking for proper alignment, levelness, and squareness of the framework, as well as load testing the framework to ensure that it can resist the design loads.

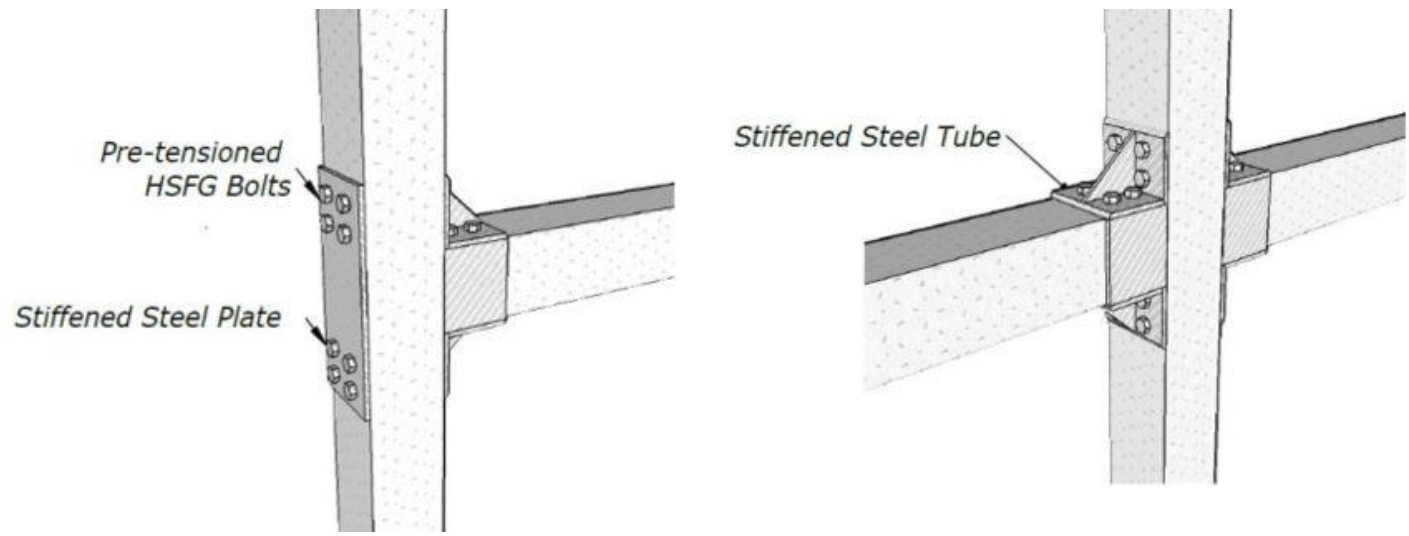


Figure 20: joinery details of beam and column

5. ENGINEERING AND OPERATIONS

FLOORING:

1. Engineering design: The design of the flooring should consider the intended use, load capacity, and environmental conditions, as well as the desired resistance to termite, rust, and fire. The recycled plastic waste panels can be selected based on their strength, durability, and fire resistance properties.

2. Flooring installation: The recycled plastic waste panels can be installed using standard flooring installation techniques, such as floating, glue-down, or mechanical attachment. The installation should be performed according to the manufacturer's instructions and any applicable building codes and standards.

3. Maintenance and repair: The flooring should be maintained and repaired regularly to ensure that it remains resistant to termite, rust, and fire. This may include cleaning the surface, repairing any damaged panels, and applying a protective coating or sealant to prevent moisture and other environmental damage.

WALL:

1. Wall installation: The recycled plastic waste panels can be installed using standard wall installation techniques, such as framing, fastening, and sealing. The installation should be performed according to the manufacturer's instructions and any applicable building codes and standards.

2. Testing and certification: The wall should be tested and certified to ensure that it meets the desired properties, such as low water absorption and heat insulation, as well as wind load capacity. This may include testing the panels for water absorption, heat transfer, and wind pressure resistance.

3. Maintenance and repair: The wall should be maintained and repaired regularly to ensure that it remains resistant to water absorption, heat, and wind pressure. This may include cleaning the surface, repairing any damaged panels, and applying a protective coating or sealant to prevent moisture and other environmental damage.

ROOF:

1. Engineering design: The design of the roof should consider the intended use, climate conditions, and load capacity requirements, as well as the properties of the eco roof sheets such as resistance to temperature, moisture, fungus, and durability.

2. Roof installation: The eco roof sheets can be installed using standard roofing installation techniques, such as framing, fastening, and sealing. The installation should be performed according to the manufacturer's instructions and any applicable building codes and standards.

3. Testing and certification: The roof should be tested and certified to ensure that it meets the desired properties, such as resistance to temperature, moisture, fungus, and durability. This may include testing the sheets for temperature resistance, moisture absorption, and resistance to fungus growth.

4. Maintenance and repair: The roof should be maintained and repaired regularly to ensure that it remains resistant to temperature, moisture, fungus, and other environmental factors. This may include cleaning the surface, repairing any damaged sheets, and applying a protective coating or sealant to prevent any damage.

6. ARCHITECTURAL DESIGN

- Foundation- Each module is supported by Concrete slab of 250mm x 250mm x 500mm.
- Column - Every unit stand on an independent lightweight structural framework made of Mild steel. Ms hollow box section of size 50mm x 50mm x 2mm
- Flooring- Recycled plastic waste panels are used which is resistant to termite, rust and fire.
- Metal Bracing to withstand lateral shockwaves of earthquake.
- Wall- Recycled plastic waste panels are used for walls protecting the interior from heat as it absorbs heat. Water absorption value is as low as 0.25 %
- Roof- Eco roof sheets are installed as a roofing material that is resistant to temperature, moisture, fungus and possess high durability.

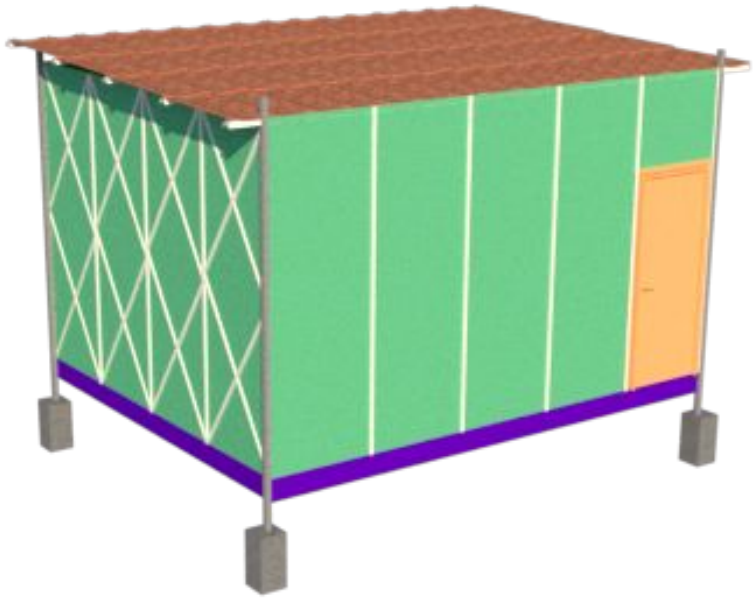


Figure 21: Module View

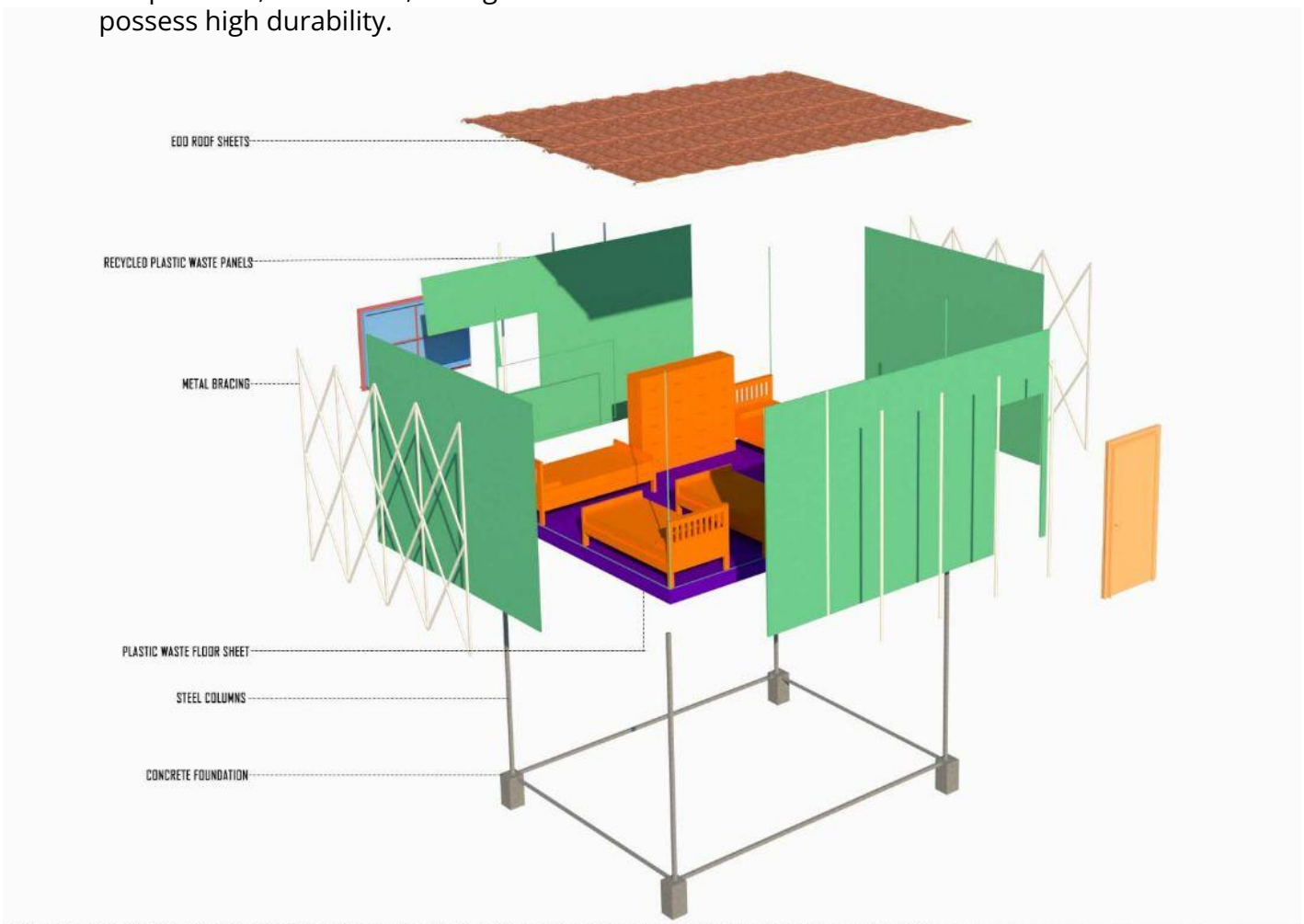


Figure 22: Exploded view of a single module

Module development

A standard 5m x 4m module can house a maximum of 4 people, though if desired the area can further be increased by adding another module. The multiplication of units is possible linearly to create a create a continuous shared spaces.
Module for the family can be made by merging the beds together. The general module is provided with beds and storage space for each inhabitant.
Openings are provided on the opposite sides of the module allowing comfortable cross-ventilation.

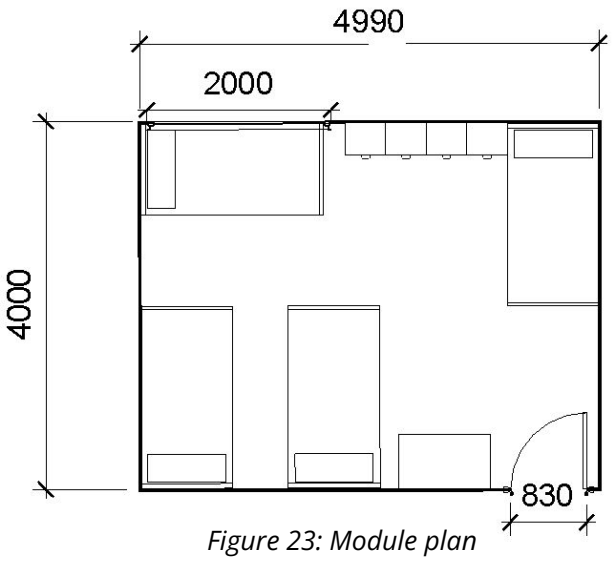


Figure 23: Module plan

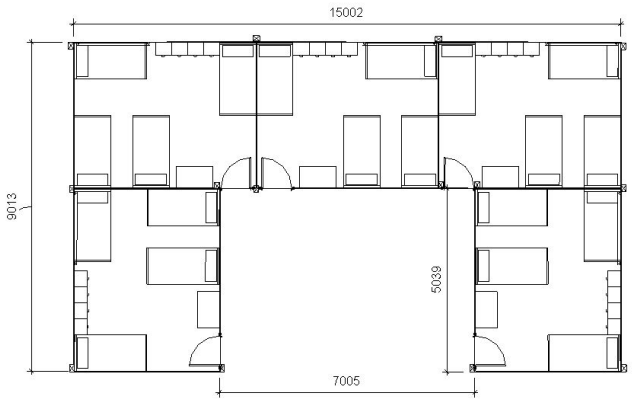
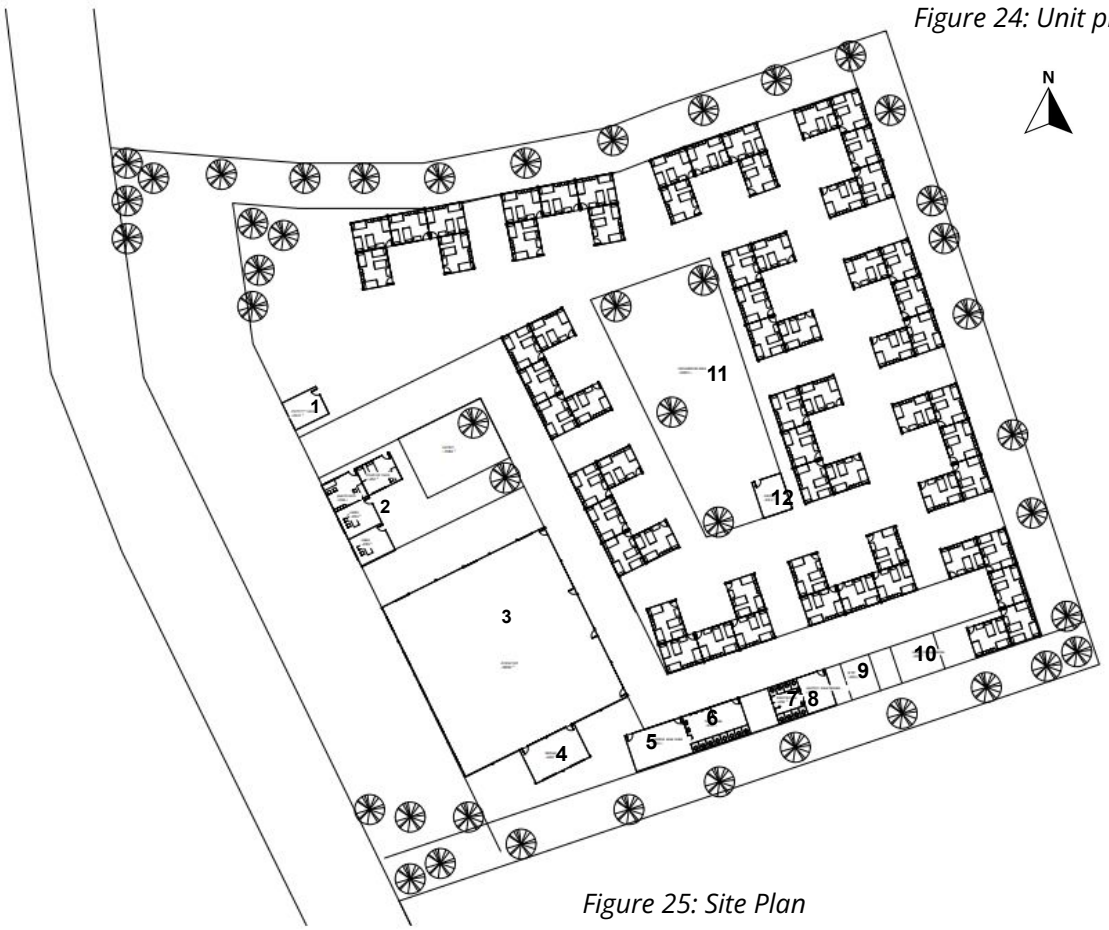


Figure 24: Unit plan

Site development

The spaces on site are planned in such a way so as to provide comfortable and secured spaces for all the users. The division of spaces is done considering the needs of the worker. Each of the spaces are temporary so as to be assembled and dismantled as per requirements.



1. Service Room
2. Admin Area
3. Dining Area
4. Kitchen
5. Male Washing Area
6. Male toilet
7. Female toilet
8. Female Washing Area
9. STP
10. Water Storage
11. Recreational Area
12. Creche

Figure 25: Site Plan

The total area of the site available wa 8000 sq.m. which was far greater than the required area. Therefore, the usable site area was 4960 sq.m. as per our requirement.

7. AFFORDABILITY

Cost-effective construction was critical for both users and stakeholders. The majority of construction worker housing colonies are developed by setting aside a percentage of the budget for such colonies. Saving money on construction housing is a common way to cut costs. Creating the module with affordability in mind meant going above and beyond current market expectations.
Along with lowering construction costs by increasing life cycle, reusability, and modularity. This approach can be seen in the following module design categories:

FOUNDATION AND PLINTH
Contractor currently used a one time usage pcc or brickbats as foundation. Not only the cost of construction of these type of foundation is high but also these cant be transported thus need to be get broken after use.
Whereas our compact and isolated solid RCC foundation is not only cost effective but also stackage which makes them easy transportable.

MATERIALS
Original units on site are made up of sandwich panels which are not only expensive but also has high embodied carbon value because of the extensive use of metal in it therefore we have utilized ricron panels which is a new technological solution for recycling waste making it environment friendly as well as the cost and embodied carbon value of these type of panels are very low comparatively. Furthermore, Fiber Cement panels are used as flooring which is also a cost effective material.

MODULAR FROM INSIDE
Original units on site are dedicated only to a bachelors type internal layout, but this type of internal layout will not work on other sites with family workers too, so we designed an internal layout that adjusts according to the user, whether it is just bachelors or families with kids or two couples, thus making the overall design modular not only from the outside but also from the inside too.

INTERNAL FITTINGS (ELECTRICAL AND WATER):
The current scenario employs yellow CFL bulbs, fans, buckets, and commodes in restrooms. These are inefficient in terms of energy and resources. Instead, using dual flush toilets, aerators, and flow fixtures saves 40-50% of the water. Using LED bulbs and high-efficiency appliances for ventilation, storage, and other purposes saves 80% of the energy.

TRANSPORTATION, REUSABILITY, AND LIFECYCLE:
A collapsible frame, panels based on recyclable waste, an compact rcc foundation, and internal fittings were all selected for their reusability and life cycle. All of them require minimal intervention and maintenance and are simple to set up and use, significantly improving living conditions over what the market currently provides. Because the frame is collapsible, it is simple to fold and transport using trucks.

7. AFFORDABILITY

COST ESTIMATION SUMMARY (PER UNIT)					
1. WALL PANEL	AREA	COST (per sq.m.)	FINAL COST		
Ricron Plain Sheet - 30mm	49.71	450	22369.5		
2. ROOFING AND FLOORING	AREA	COST (per sq.m.)	FINAL COST		
Roof - Ricron Eco Roof	24.65	350	8627.5		
Floor - Cement Board 25mm	19.44	310	6026.4		
3. DOOR	AREA	COST (per sq.m.)	FINAL COST		
UPVC (20 yr lifespan)	1.89 (0.9*2.1)	2695	5093.55		
4. WINDOW	AREA	COST (per sq.m.)	FINAL COST		
Louvered window	2.4 (2*1.2)	1250	3000		
5. FURNITURE	QUANTITY	COST	FINAL COST		
Almirah	1 (with 4 divisions)	12000	12000		
Bed	4	4000	16000		
Table	1	1500	1500		
6. FOUNDATION	VOLUME	COST	FINAL COST		
Precast Concrete Foundation	0.25 (0.0625*4)	5000	1250		
7. STRUCTURE	VOLUME	DENSITY	WEIGHT	COST (per Kg)	FINAL COST
Hallow square section	0.04028 (0.003*0.07*50.1)	7840	315.7952	36	11368.6272
L section	0.003492 (0.003*0.97*12)	7840	27.37728	36	985.58208
C section	0.02592 (0.003*0.144*60)	7840	203.2128	38	7722.0864
Flat Bar	0.024 (0.01*0.1*24)	7840	188.16	30	5644.8
8. FURNITURE	QUANTITY	COST	FINAL COST		
Fans (1200mm Dia)	2	1300	2600		
LED Light (18W)	4	240	960		
Wiring and Switch board	-	-	1600		
TOTAL UNIT COST	106748.0457				

Table 11: Cost Estimation summary

8. INNOVATION

MODULARITY: Different layout options for different sites.

- A mobile application have been designed for contractors/construction companies which will help in providing layout options while maintaining net zero and comfort factors.
- The application would require certain inputs like number of users on site, site shape , site location , etc. which would be used in evaluating the best suitable layout option for that particular site.

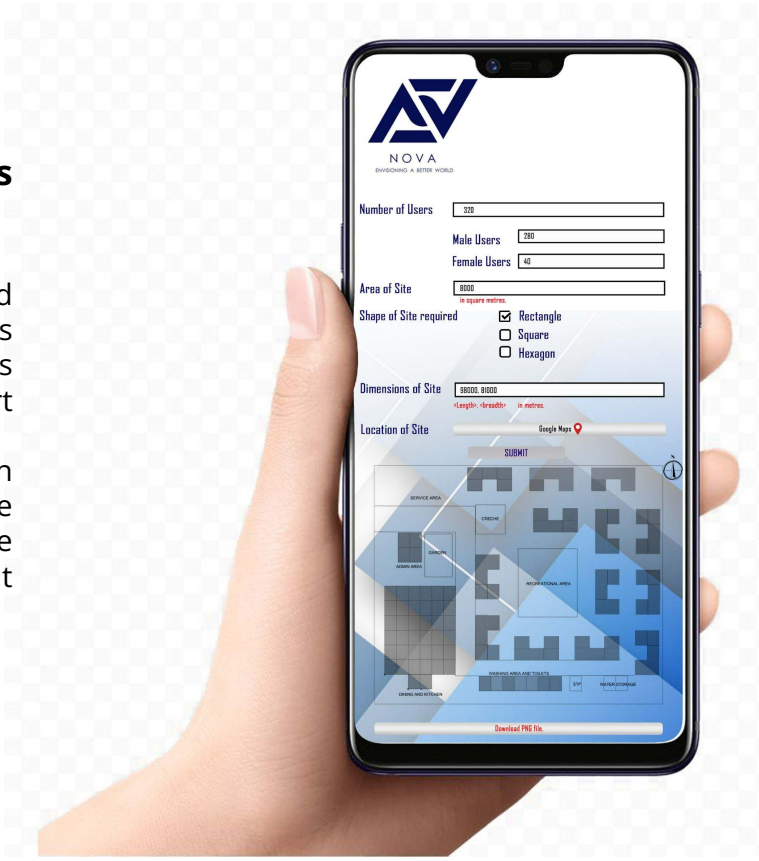


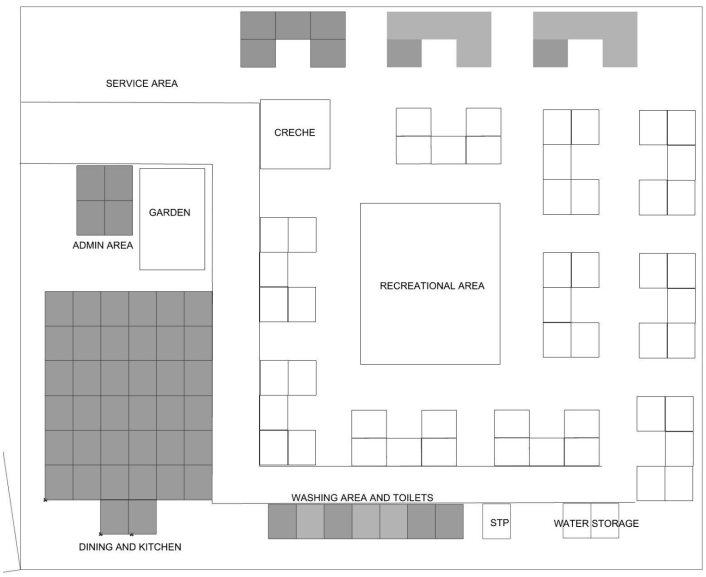
Figure 26: Mobile application

FUNCTIONS OF DIFFERENT INPUTS

NUMBER OF USERS:

- Dining unit:
  The size of dining unit will vary according to the number of users on site. The total size is calculated providing 2m2 of space per person and the number of modules are determined accordingly.
- Kitchen:
  The kitchen size is evaluating proposing one module for every 160 users. This would also vary as the number of users are increased or decreased.
- Living Units:
  This is also dependent on the number of users. The typical design of single module is proposed for 4 users and accordingly there are 20 users for one living unit. The living units will also multiply itself as the users are increased for different sites.

  In addition to this, the living unit will transformed into two storey if the area of site is not sufficient to accommodate the required number of users.



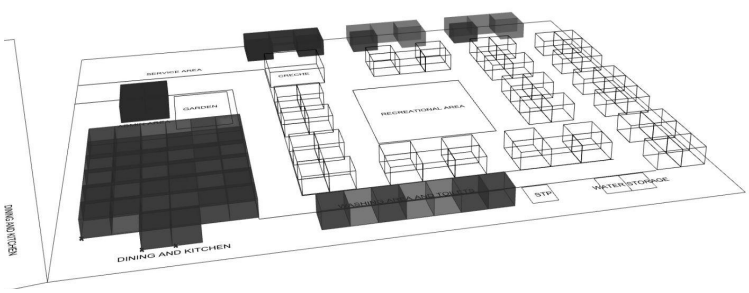


Figure 27: Site bird eye view

- Recreational area and creche:
  The area proposed for recreational facilities is also dependent on the number of users using it. An area of 1 m2 per person is given to the recreational unit.
- Male and female users:
  According to NBC standards , 1 unit for 15 users is required and there are 8 units in one module, hence this would give the number of modules required for toilet and washing area of males and females respectively.

WORKING OF DINING AREA ALGORITHM

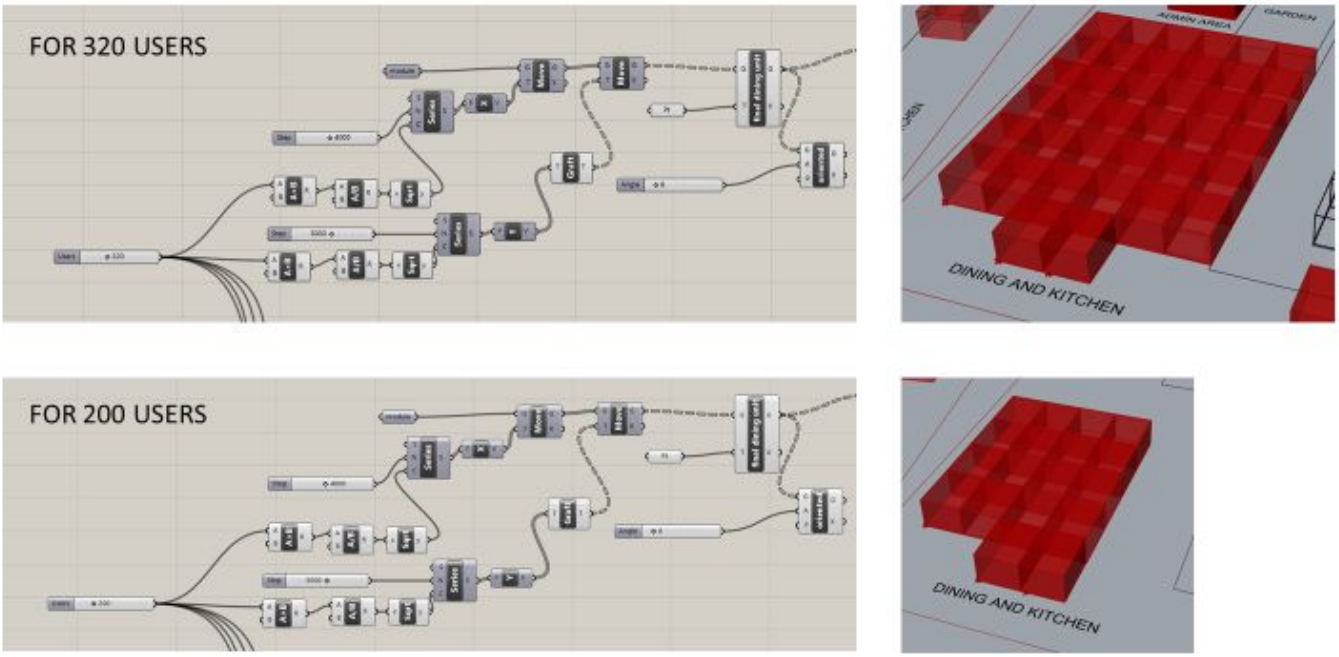


Figure 28: Site massing

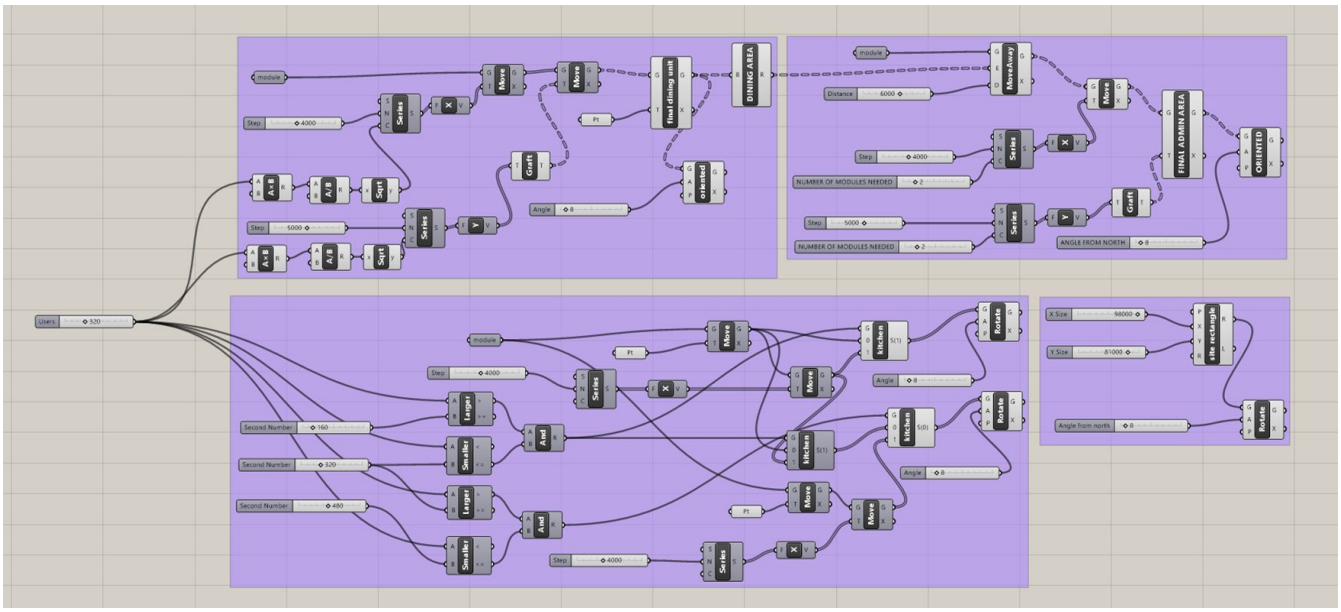
AREA OF SITE AND SHAPE OF SITE REQUIRED

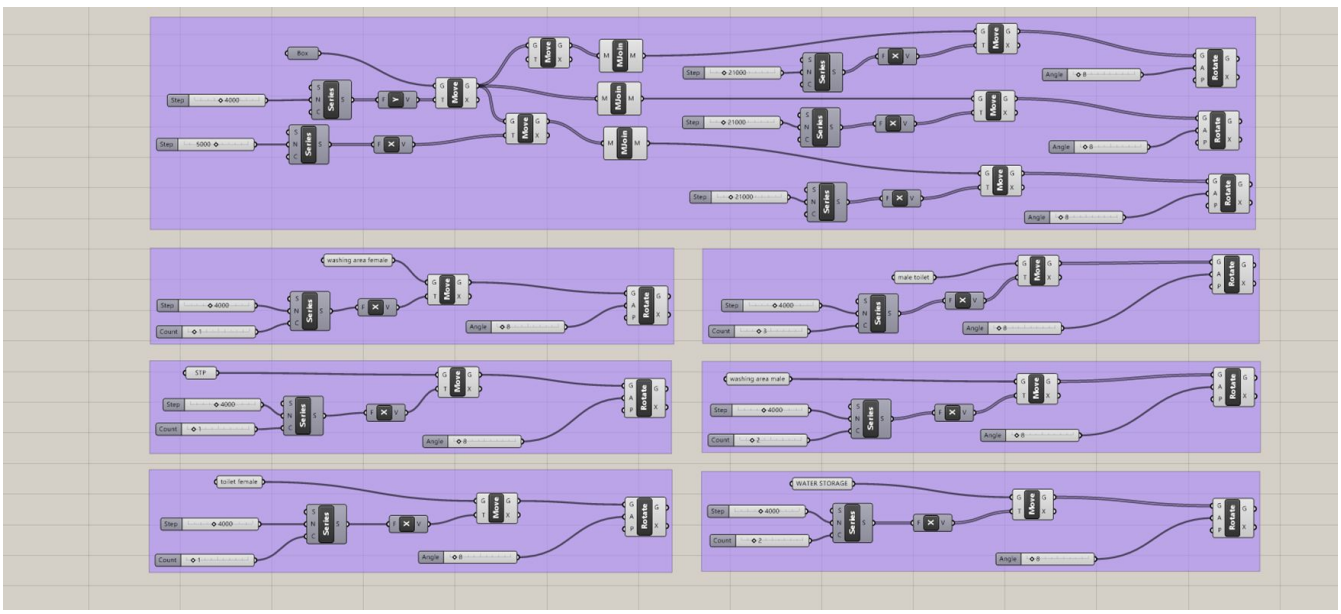
- Stp required:
  One module per 8000m2 of site area is proposed for the STP Plant on site. These number of modules will vary as the area of site will vary.
- Water Storage:
  One module per 4000m2 of site area is proposed for the STP Plant on site. These number of modules will vary as the area of site will vary.

LOCATION OF SITE

- The application will determine the angle of site from geographic north through its location input and thereafter the grasshopper algorithm will use that angle to orient the proposed layout in the best suitable orientation for that particular site.


WATER STORAGE
STP
WASHING AREA AND TOILETS
RECREATIONAL AREA
CRECHE
SERVICE AREA
GARDEN
ADMIN AREA
DINING AND KITCHEN
N
SERVICE AREA
CRECHE
GARDEN
ADMIN AREA
RECREATIONAL AREA
WASHING AREA AND TOILETS
STP
WATER STORAGE
DINING AND KITCHEN





9. HEALTH AND WELLBEING

THERMAL COMFORT

The mode of operation of the construction worker housing module is 'naturally ventilated'. The strategies for ventilation in the module include:

- As per the wind rose diagram, most of the winds for Rajkot are from southwest. To facilitate air flow in the modules for maximum hours, we have placed module diagonally along south west.
- Windows placed on opposite walls for cross ventilation are placed at optimum sill level for maximum air flow in the module.
- With the louvres we have implemented stack effect which allows hot air to escape the modules.

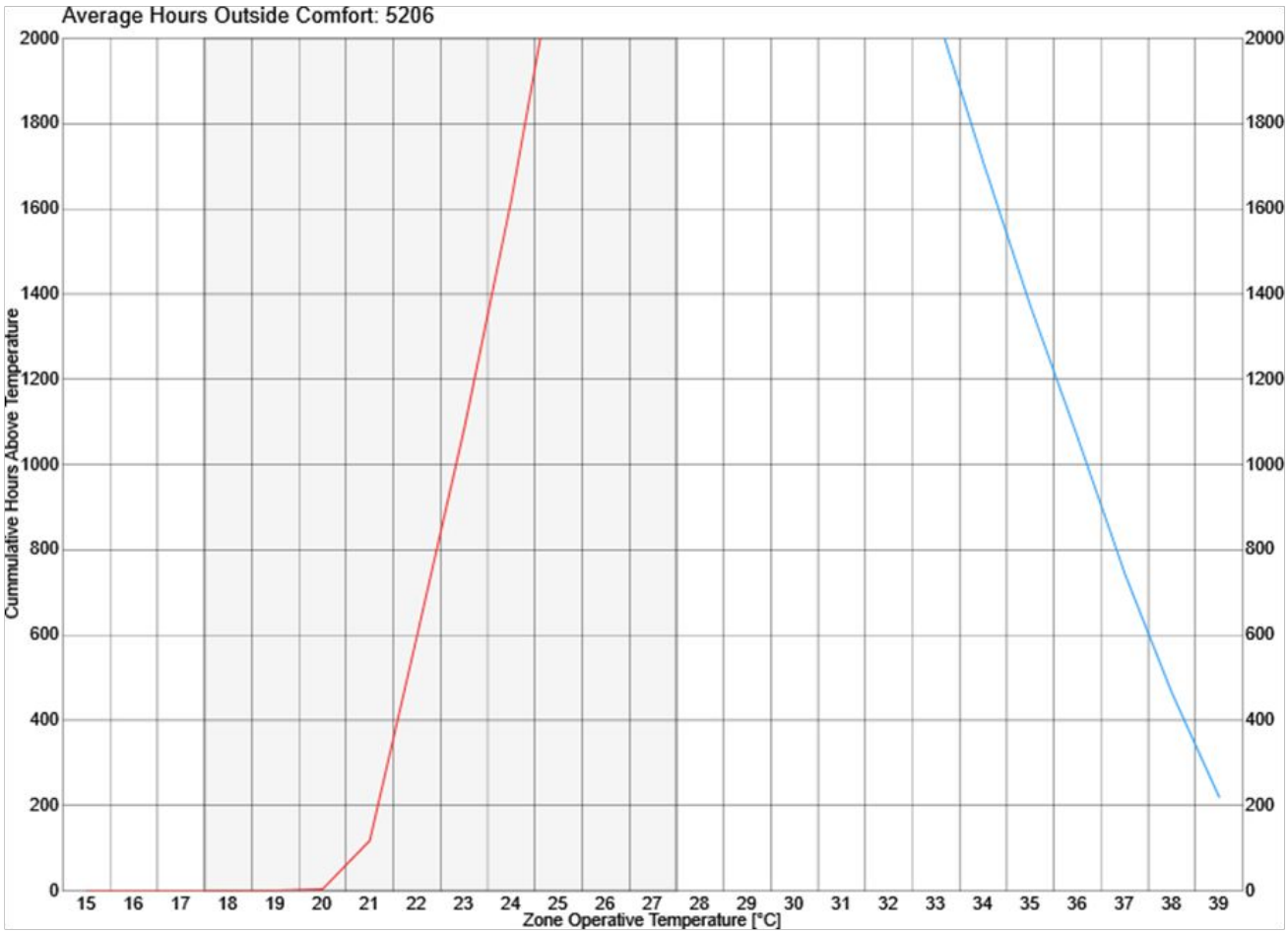


Figure 1 Annual discomfort hours result from simulation

Thermal Comfort Hours

Total operational hours for module are 15 hours per day that excludes the 9 hours working shift of the construction workers starting from 8 AM to 5 PM. So, out of 8760 total hours, the occupied hours would be 5475 hours.

The total hours outside comfort are 5206 as per simulation shown in the figure and considering the discomfort is caused during the days when related to operative temperature of the zone, giving us 3554 comfort hours.

Since the 5475 occupied hours lie between 5pm and 8AM, 3554 hours lie in occupancy hours with 1921 discomfort hours, Hence, 65 % of the occupied hours as comfort hours. These discomfort hours are majorly in the evening after 5 PM up till or less from midnight. The month of May is the peak hottest month according to Tapi, Gujrat climate zone. The operative temperature for a typical day in the month of May can be seen in the figure, where the indoor operative temperature at 8 am is more or less near 30 degrees Celsius and goes on rising till the noon.

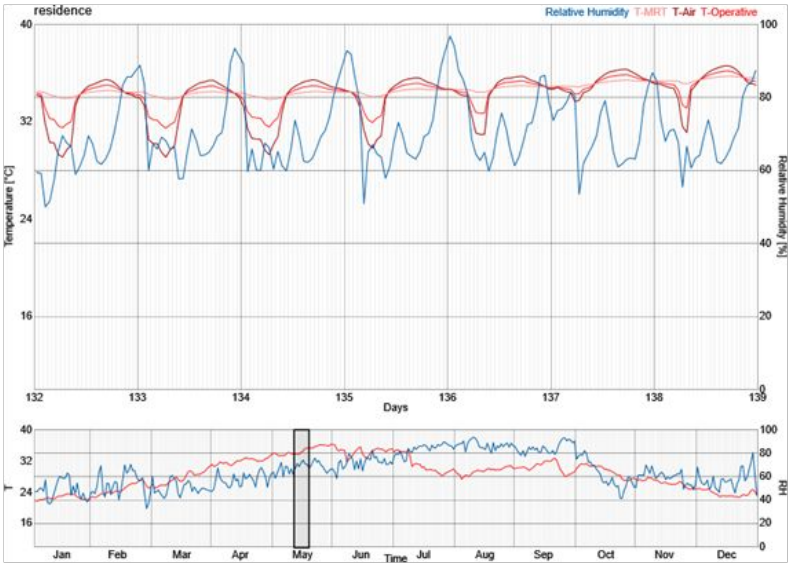


Figure 2 indoor zone Temp in the month of May.

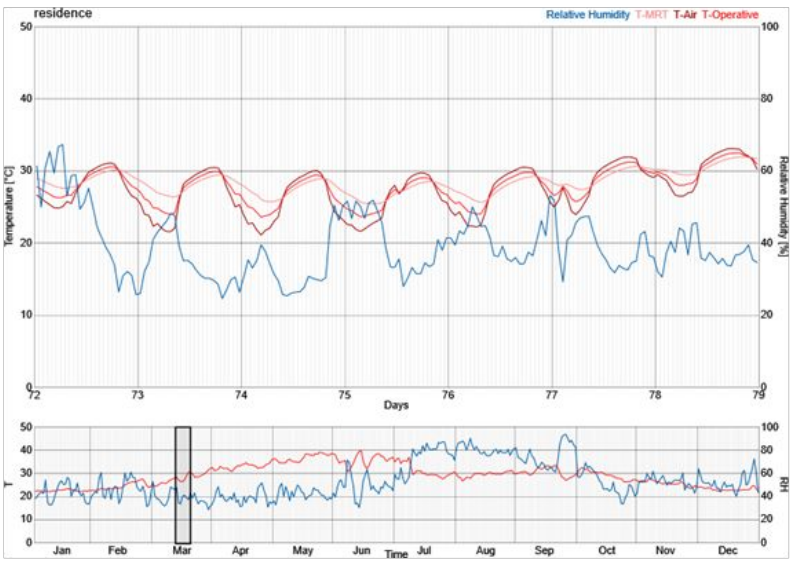


Figure 3 Indoor zone temperature in the month of March.

While the case for the month of March, the operative temperature in the unoccupied hours is above the comfortable temperature and during occupied hours, the temperature meets the comfort hour conditions.

The operative temperature at 30 is in compliant to ASHRAE standard 55 (as shown in in fig. 4)

The operative temperature at 30 is in compliant to ASHRAE standard 55 using adaptive comfort standard (ACS) model applicable to the site.

Thermal comfort is influenced by two factors i.e the humidity and dry bulb temperature. to establish the comfort band, if the relative humidity falls either below 30% or above 70% it is deemed as uncomfortable.

In compliance to ASHRAE standard 55 adaptive method operative comfortable temperature for 80 % people is 23.6˚C – 31.8˚C.

when the set temperature is 30˚ C and the means of ventilation in natural ventilation.

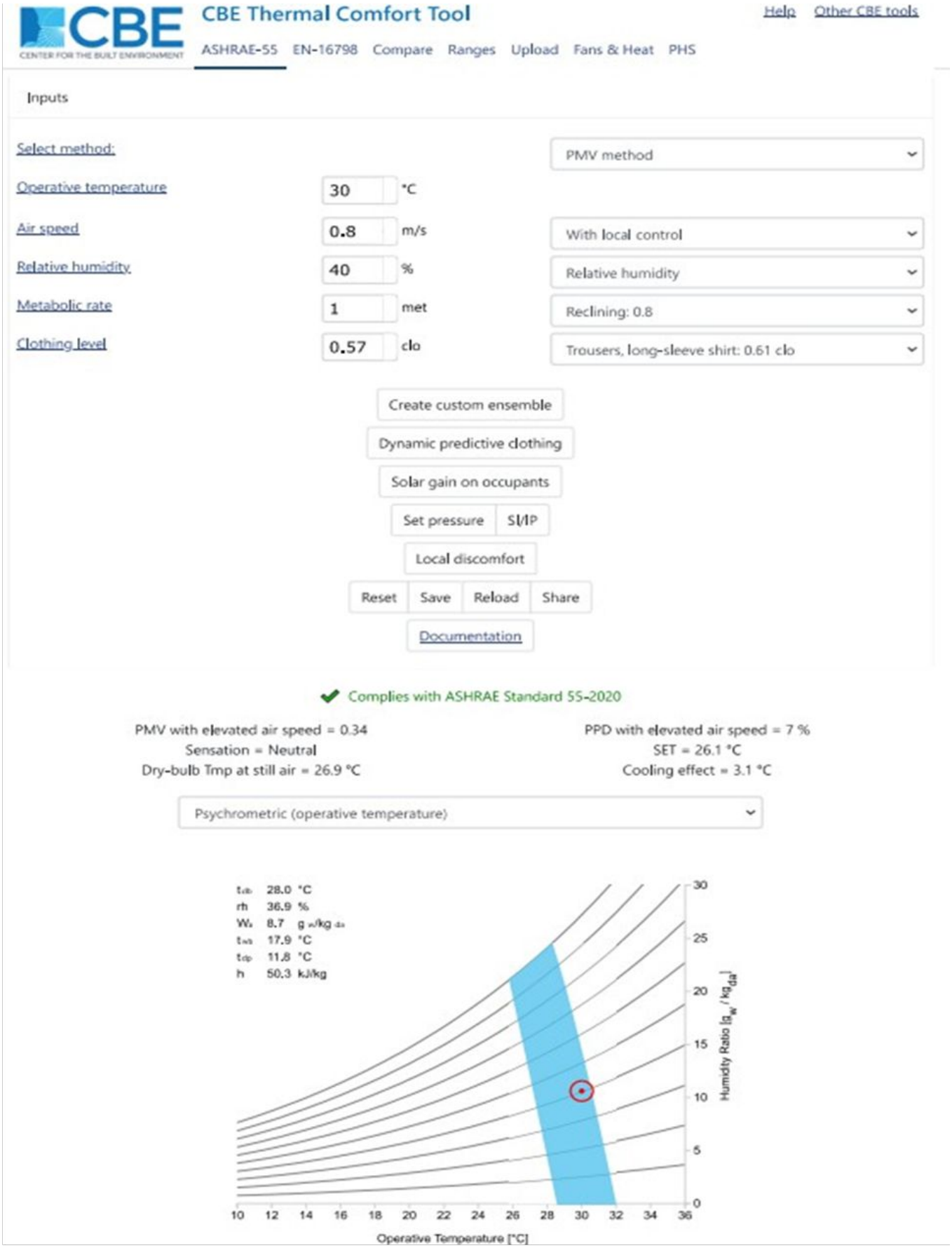


Figure 4 Compliance with ASHRAE standard 55

Figure 5 Compliance with ASHRAE standard 55

PASSIVE DESIGN STRATEGIES

Based on ASHRAE standard 55 in a naturally ventilated mode, following passive deign strategies have been implemented in the living modules.

- Walls with louvred windows shaded by overhangs, placed on opposite sides for cross ventilation.
- Flow of air in the module due to diagonally placed windows
- Louvres at the top facilitate the ventilation across the section and optimizes lux in the living modules.
- Shaded outside porch cools down air and increases acceptability range of thermal comfort and extend living and working conditions, thus reducing thermal shock in transitional spaces.
- Fans span decided as per NBC Standards, can make one feel 2.8 degrees cooler on hot days with windows closed.
- The number of comfort hours achieved: 3554 hours

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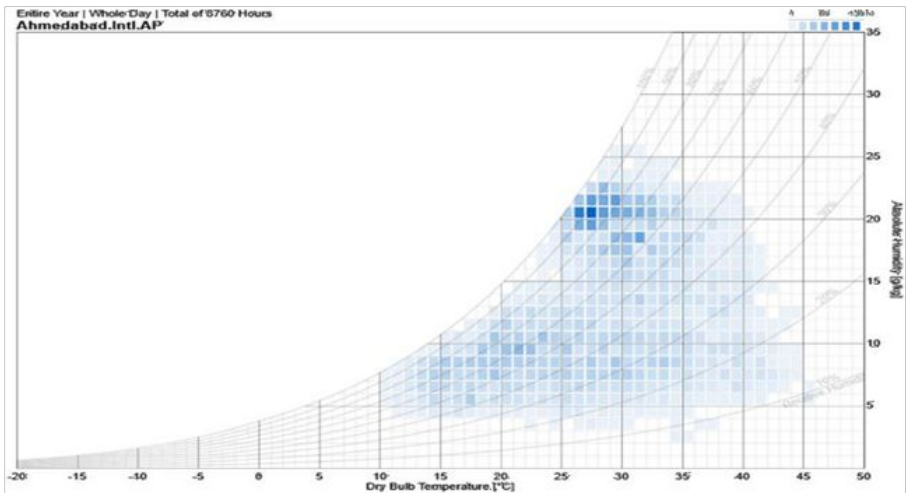


WELLNESS STRATEGIES

To reduce the extent of impact of psychological issues in the workers, wellness design strategies are an integral part of the workman habitat design.

- Courtyard planning to integrate social spaces for daily interaction.
- Use of orange light at night in the interiors of the housing module helps in managing the sleeping cloak.
- Suggesting plants like lemongrass in the vicinity for its air purifying and olfactory properties.
- Use of sound proof materials for acoustical comfort.

Space type	No. of occupant	R_p (l/s.person)	Floor Area (m^2)	R_a (l/s.m^2)	Ventilation rate (l/s)
Module (Bachelors)	4	2.5	20	0.3	16
Module (family	4	2.5	20	0.3	16
Kitchen	30	3.8	40	0.6	138
Dining	320	3.8	600	0.9	1756
Daycare	20	5	72	0.9	164.8
Medical room	5	2.5	20	0.3	18.5
Office	4	2.5	20	0.3	16
Guard Room	1	5	20	0.3	11

Table: Natural ventilation

The mode of operation for each space is **'naturally ventilated.**

Placement of windows in the modules facilitate Cross ventilation. The winds are mostly south west so the orientation of the modules facilitate flow of air in the module. In the absence of vegetation on site, the kitchen garden plants will improve the air quality.

The ACpH of the Space type required AcpH module(bachelors) module (family) spaces as per NBC is as follows:

- Equal area inlet and outlet openings at same sill level to maximise flow per unit area of openings.
- Allowing the windows to open directly into open spaces, possible in our courtyard clustering.
- Fan sizes chosen as per usable area of room.
- Height of the fan blades as per formula (3H+W)/4 from the floor.

Space type	Required ACpH
Module (bachelors)	4
Module (family)	4
Kitchen	15
Dining	8
Daycare	6
Medical room	8
Office	6
Toilet	6
Bathroom	6
Guard Room	4

10. VALUE PROPOSITION

The value proposition of the Construction worker housing project by Team Nova can be described as follows

1. **Affordable housing:** The project offers affordable housing for construction workers who often struggle to find decent and affordable accommodation near their workplace

2. **Sustainable design:**

- The dwelling units are made of sustainable materials, are energy-efficient, and are ecologically friendly in order to lessen their carbon impact and help create a cleaner, greener environment.
- Recycled plastic panels are used for the walls, roof, and floor, which helps to lessen the environmental impact of plastic waste and promotes the development of a sustainable future for the globe.
- They are resistant to dangers from fire, acid, and termites, as well as being robust, long-lasting, economical, and water-efficient

3. **Comfortable living:** The housing units are designed to provide comfortable and hygienic living conditions for construction workers, including proper ventilation, lighting, sanitation facilities, and clean drinking water.The modules are positioned in order to improve thermal conditions passively while protecting the environment and maintaining user comfort.

4. **Social impact:** The project aims to create a positive social impact by improving the living standards of construction workers and promoting social inclusivity and equality.

5. **Scalability:** The housing units are designed to be scalable, meaning they can be easily replicated and scaled up to meet the housing needs of a larger population of construction workers in different locations.

6. **Net Zero solution:** Utilising net zero strategies, such as deploying biogas plants and water-efficient fixtures, allows for the maximisation of positive effects while limiting negative ones.

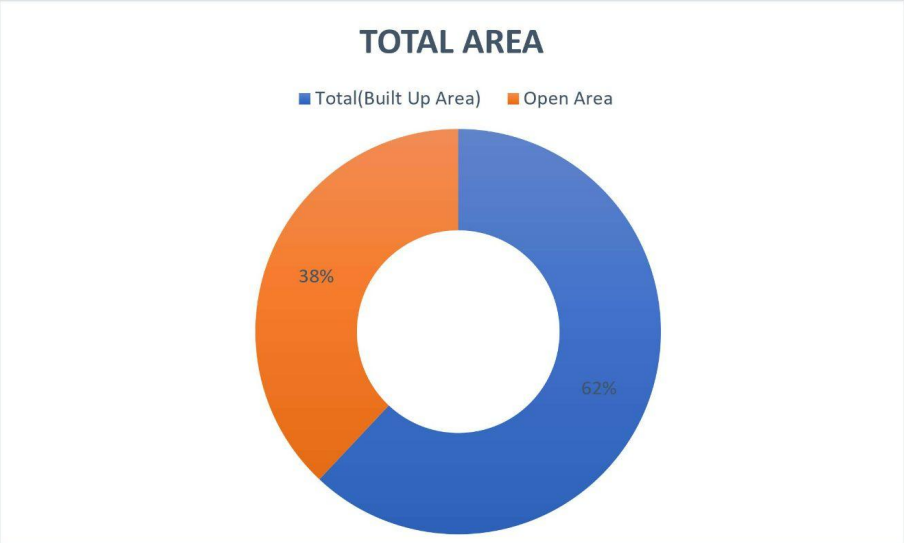
APPENDIX

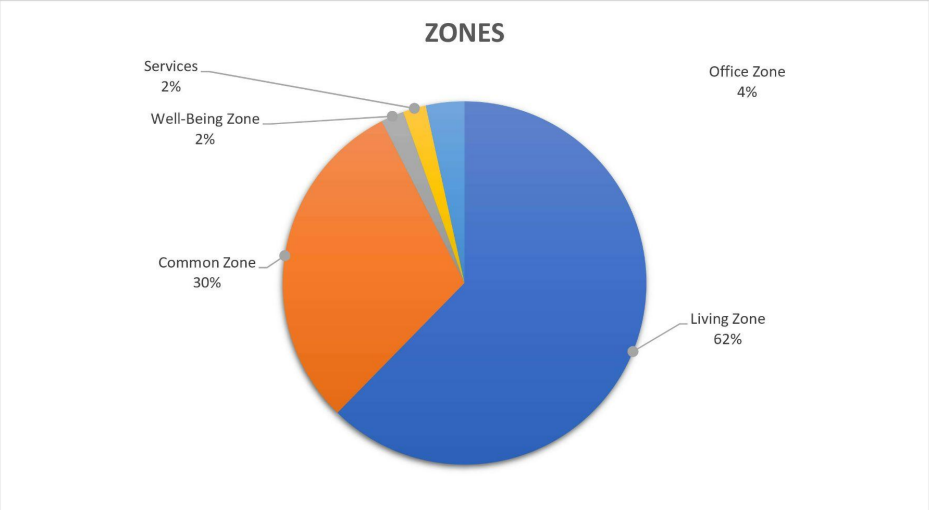
1. BUILDING AREA PROGRAM

- The areas are planned in the multiples of single module unit of 5m x 4m.
- The layouts of living zones are designed according to NBC guidelines, Time Saver's and Neuferts' Data.

S.NO.	FUNCTION	NO. OF USERS (PER MODULE)	AREA IN SQ.M (PER MODULE)	NO.OF MODULE	TOTAL AREA IN SQ.M. (ACC. TO NO OF MODULES REQUIRED)	CONDITIONING
	Living Zone					
1	Sleeping unit					Unconditioned
	Singles	4	20	64	1280	
	In Families	1(Family)	20	20	400	
AREAS IN SINGLE UNIT	Component / Size of 1 unit / No.Of Units / Total Area Bed 1.62 5 8.1 Storage 0.355 5 1.775 Circulation 11.125 21					
2	Bathroooms and Washing Area					Unconditioned
	Male	10	20	2	40	
	Female	10	20	1	20	
AREAS IN SINGLE UNIT	Component / Size of 1 unit / No.Of Units / Total Area Bathing Space 0.81 10 8.1 Circulation 12.9 21					
3	Toilets					Unconditioned
	Male(WCs + Urinals)	8	20	3	60	
	Female	8	20	1	20	
AREAS IN SINGLE UNIT	MALE / Size of 1 unit / No.Of Units / Total Area WCs 1.2 8 9.6 Urinals 0.1 2 0.2 Circulation 11.2 21 FEMALE / Size of 1 unit / No.Of Units / Total Area WCs 1.2 8 9.6 Circulation 11.4 21					
	Common Zone					
5	Dining Unit	320	600	30	600	
6	Kitchen Unit		16	1	20	Unconditioned
7	Recreational Unit	320	300	15	300	
	Well-Being Zone					
8	Medical Room	5	21	1	20	Unconditioned
9	Creche	30	40	2	40	

	Services					
10	Storage		20	1	20	
11	STP		20	1	20	Unconditioned
12	Electrical Service Room		10	1	20	
	Office Zone					
13	Cabins	2	10	2	40	
14	Washroom	10	6	1	20	
15	Offices	2	10	1	20	Unconditioned
16	Canteen		12	1	20	
	Total			148	2960	
	25% Circulation				2000	
	Total(Built Up Area)				**4960**	
	Open Area				**3040**	
	Total Site Area				**8000**	
				For 320 Users		





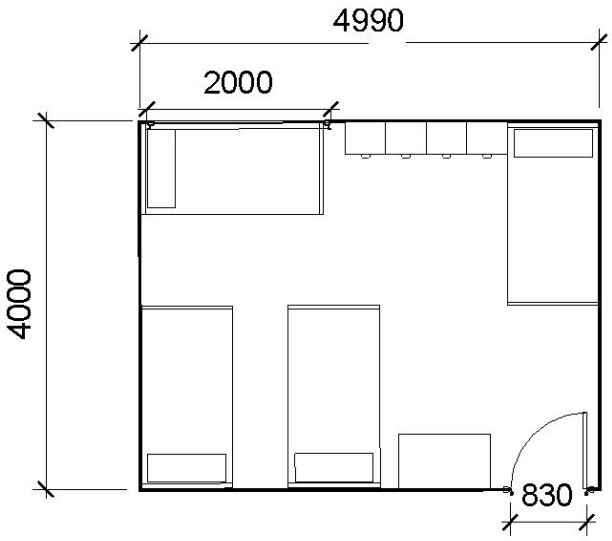


Figure 1a. Module internal layout

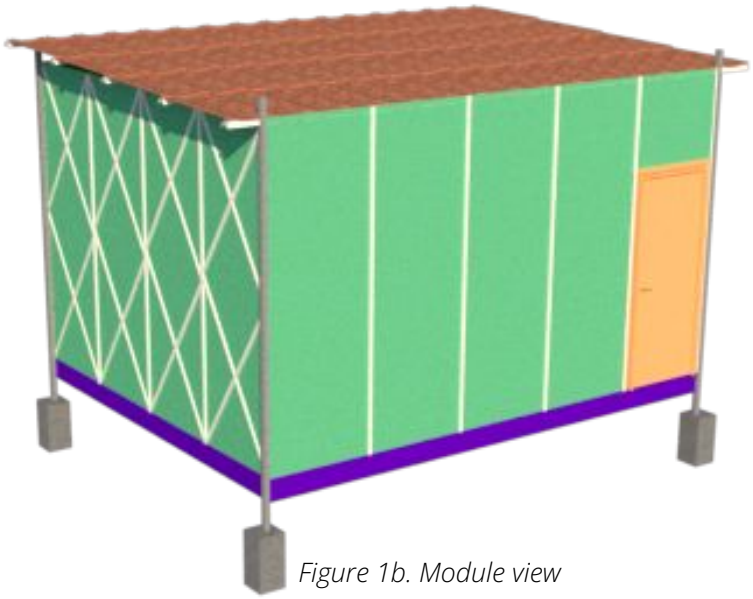


Figure 1b. Module view

Figure 1c. Module internal layout

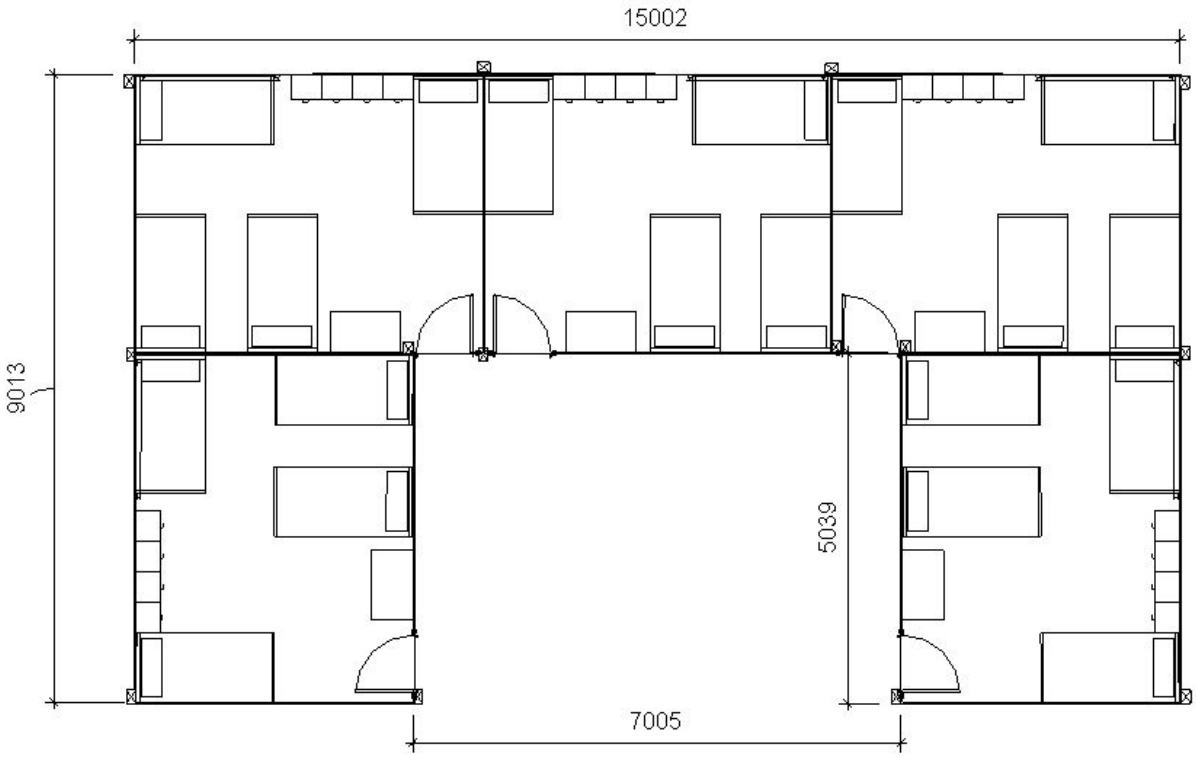


Figure 2a. Unit internal layout

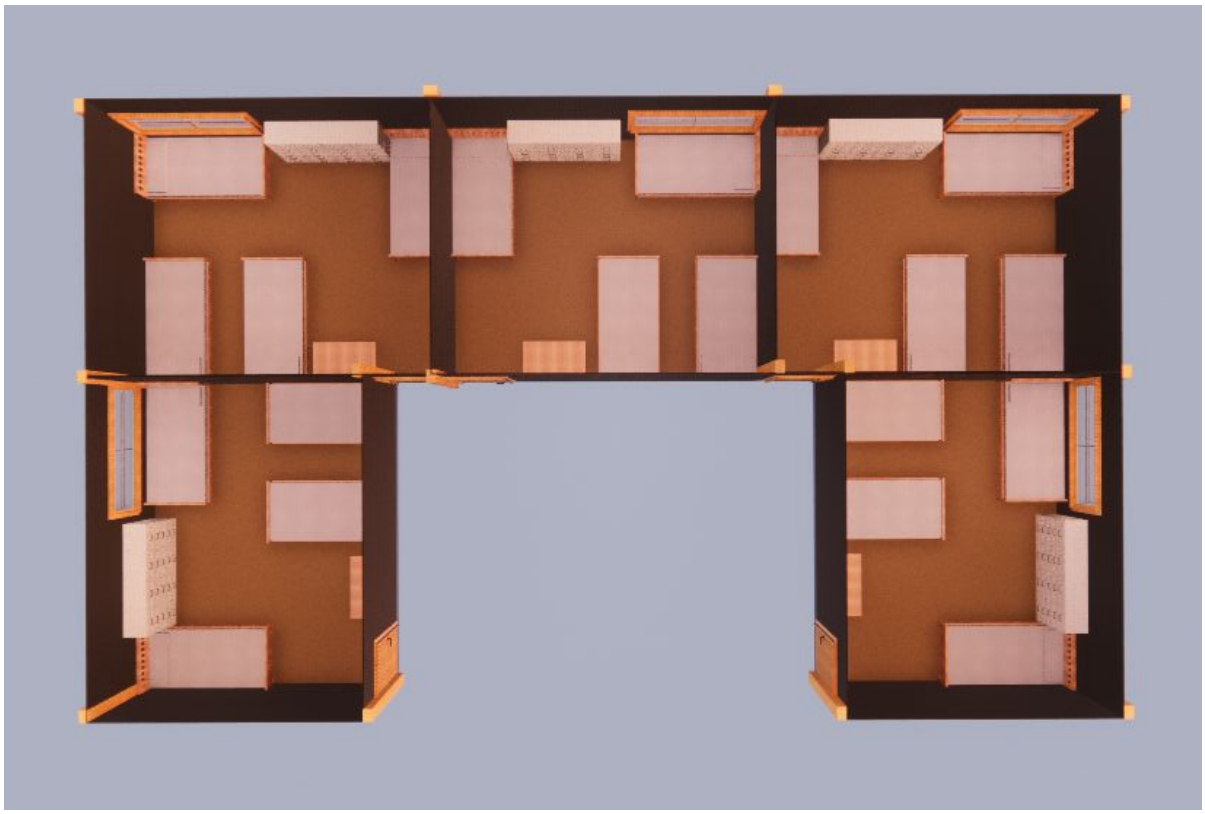


Figure 2b. Unit internal layout

Figure 3a. Site view

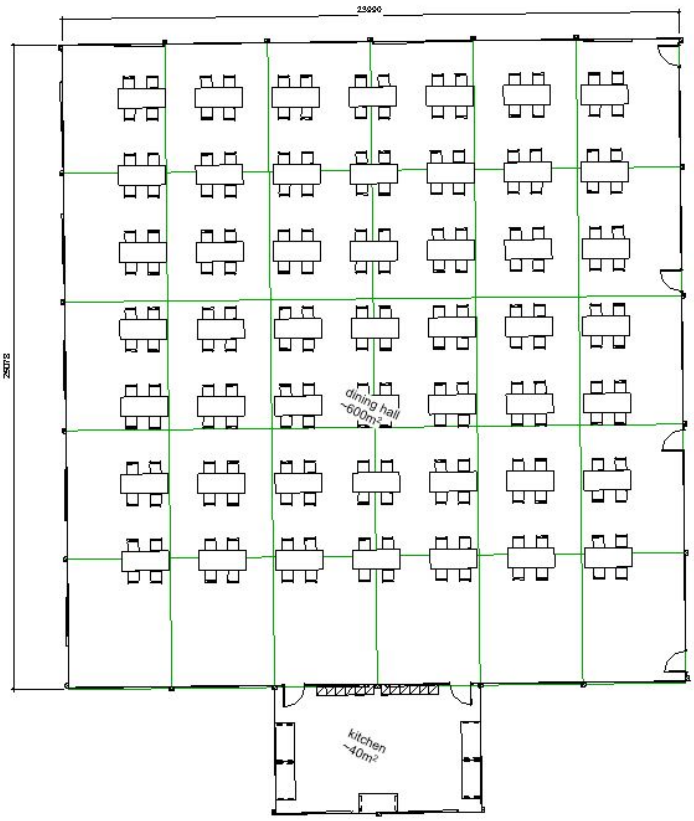
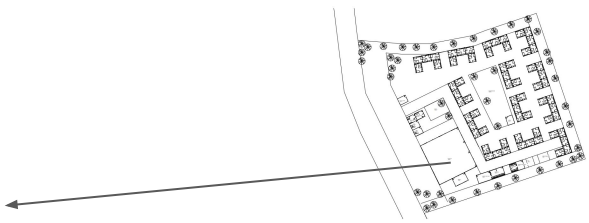


Figure 4a. Dining area plan



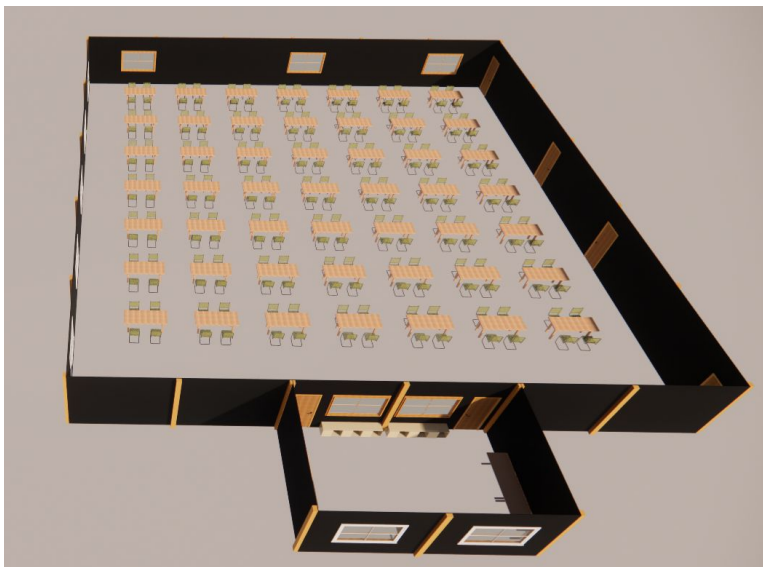
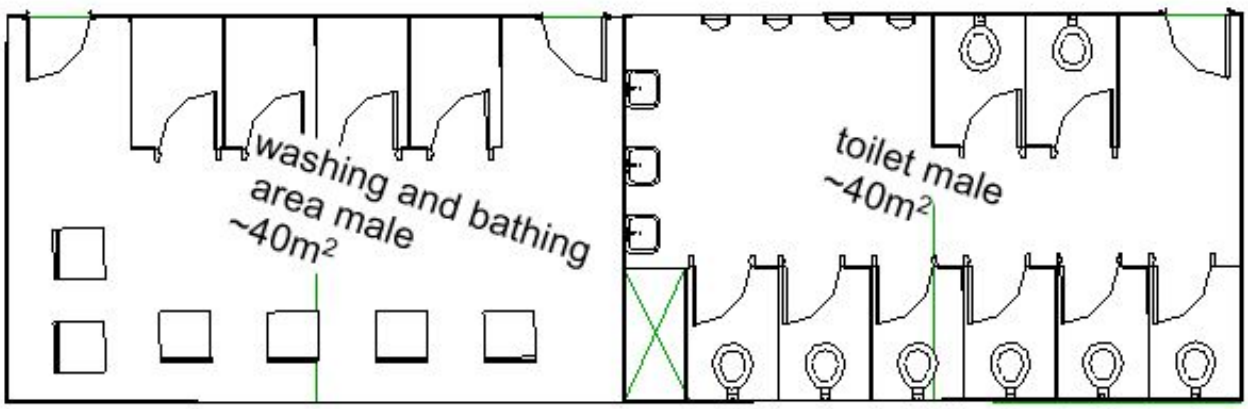


Figure 4b. Dining area view

Figure 5. Guard room, medical room and cabins plan



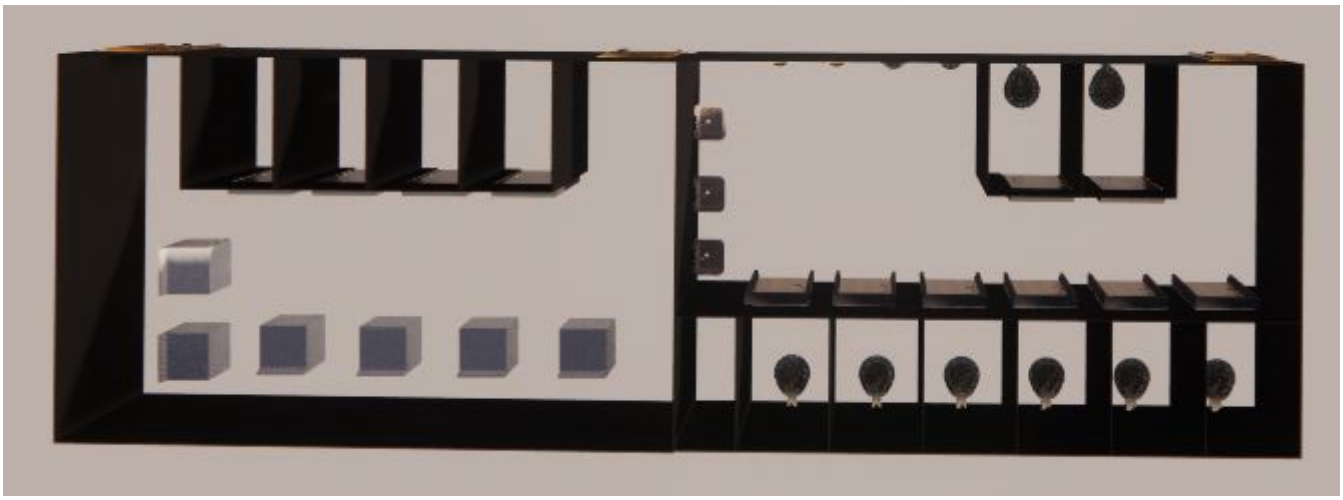
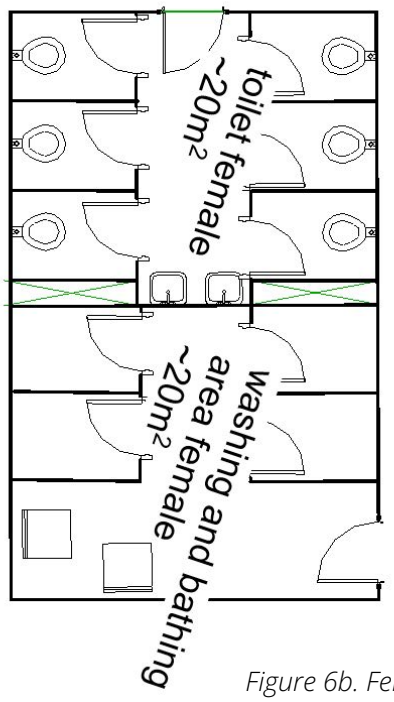


Figure 6a. Male toilets, washing and bathing area plan



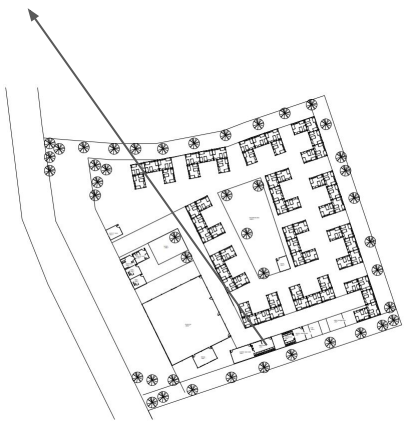


Figure 6b. Female toilets, washing and bathing area plan

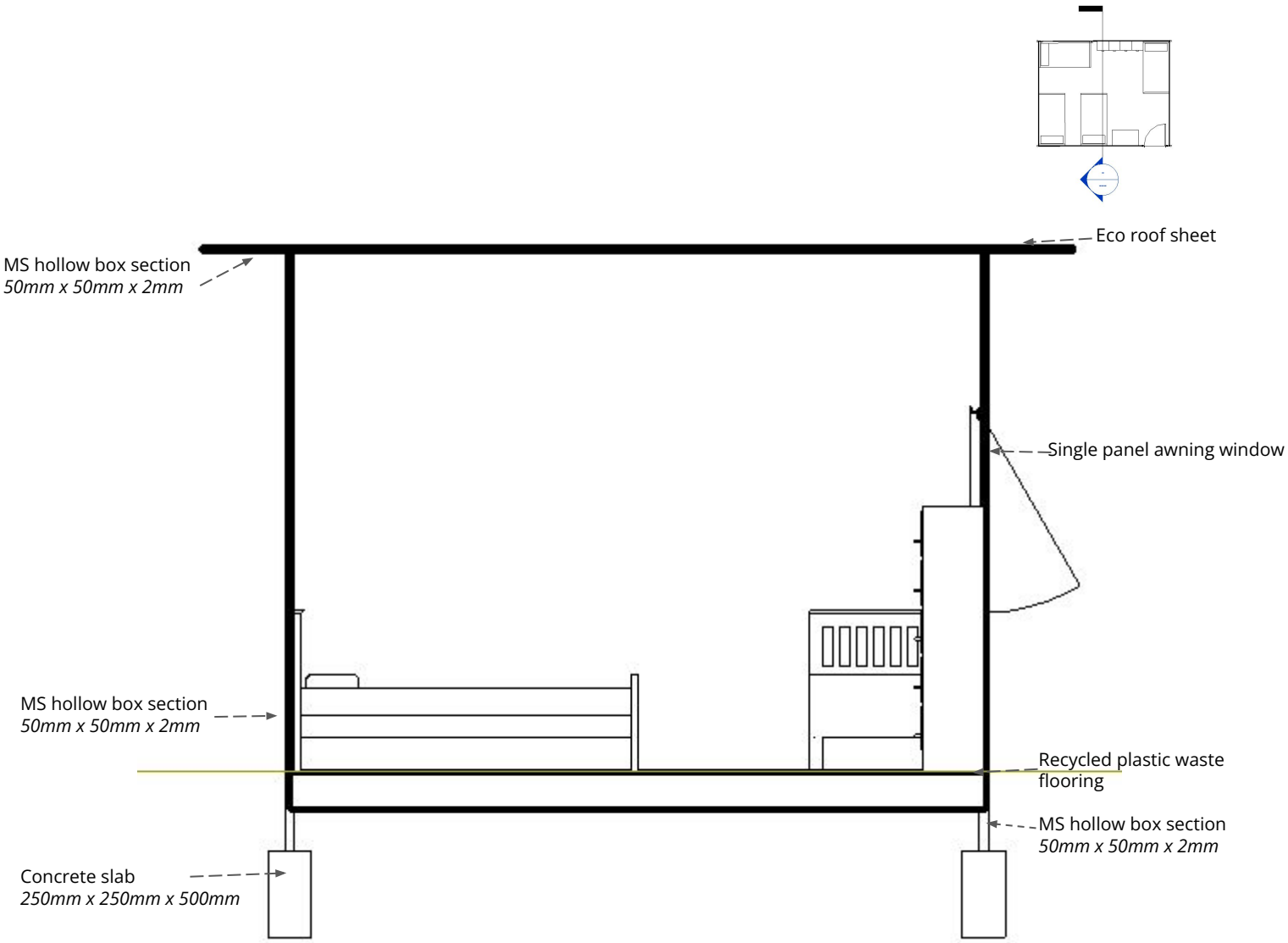


Figure 7a. Module section

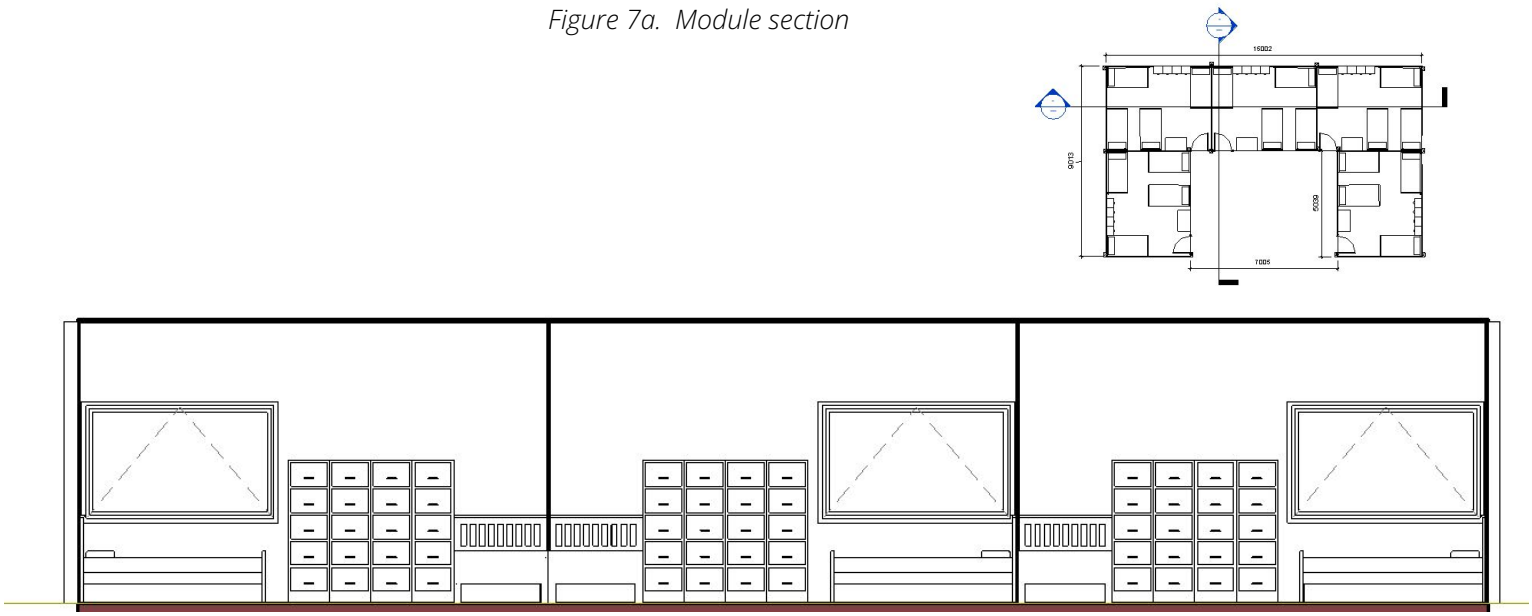
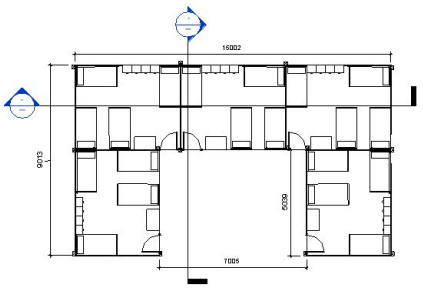


Figure 7b. Unit section X-X'



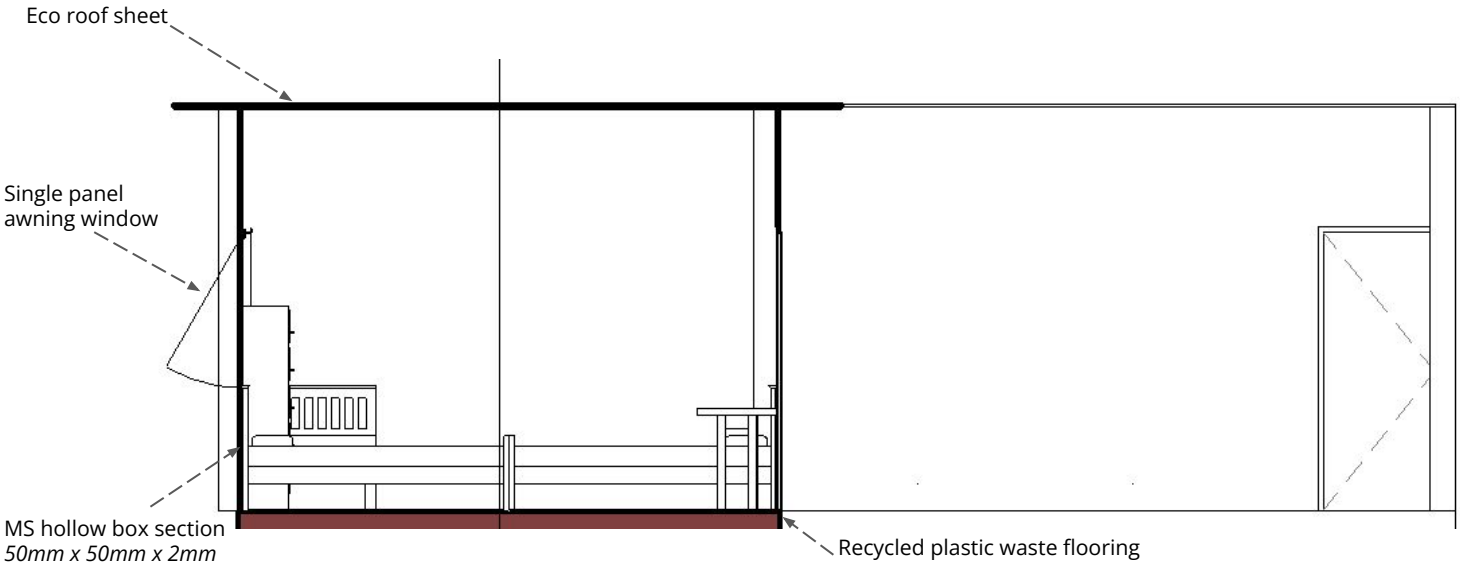


Figure 7b. Unit section Y-Y'

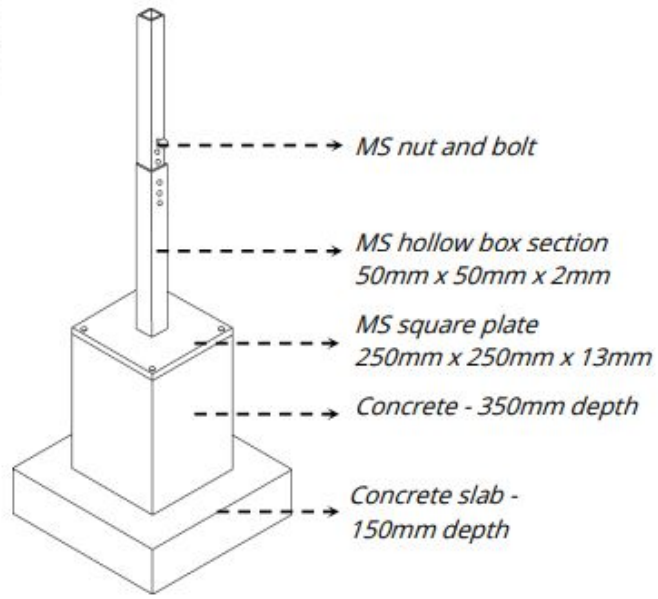


Figure 8. Foundation Detail

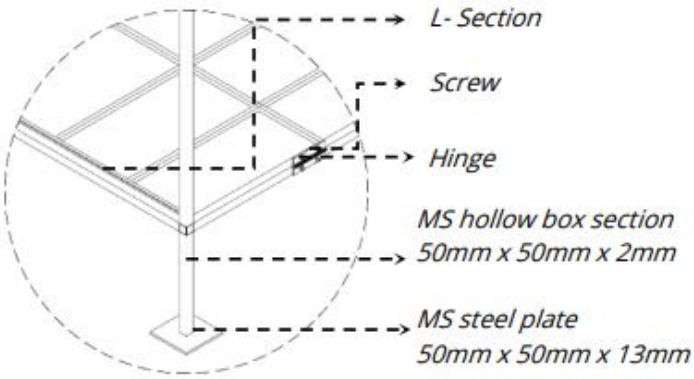
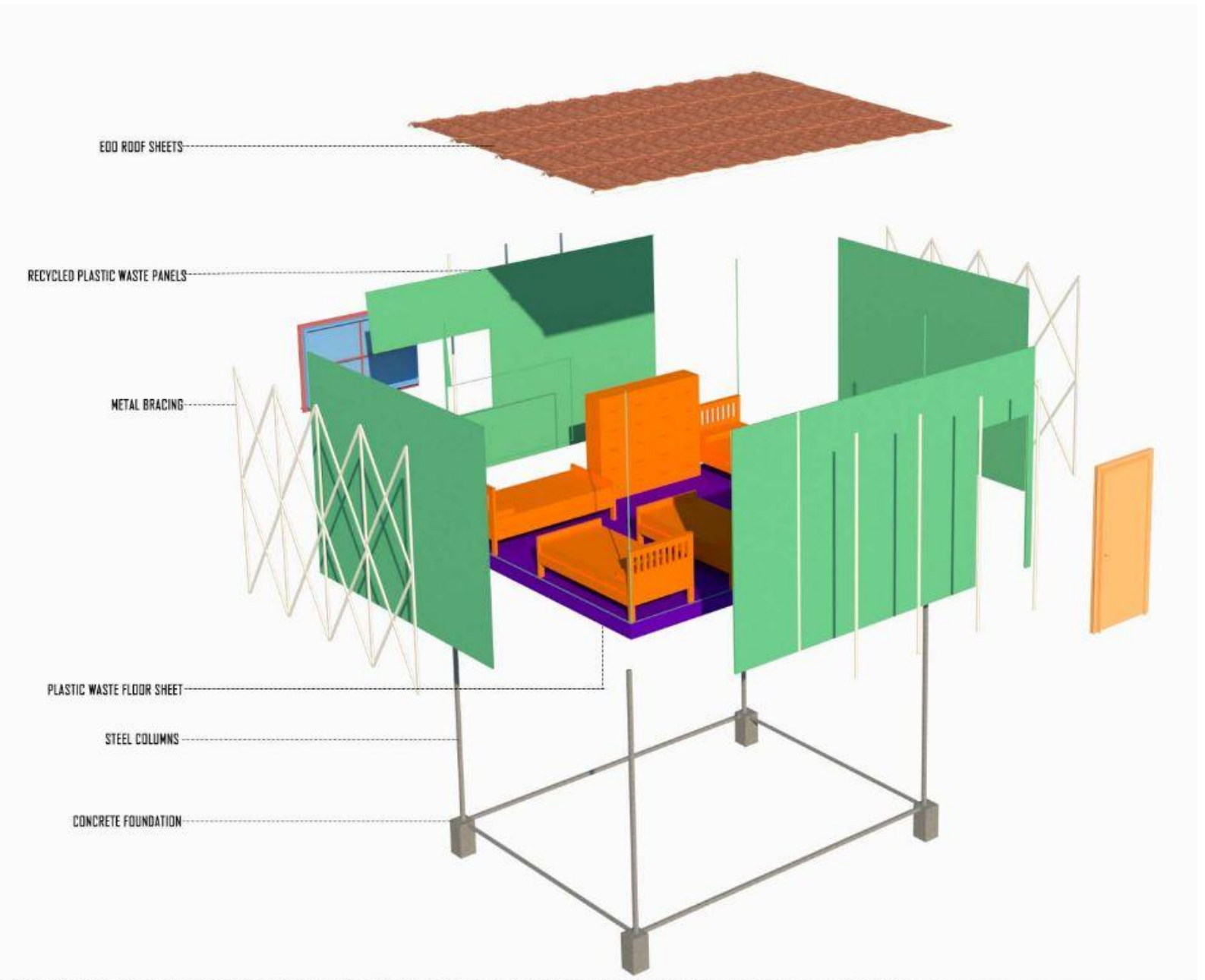


Figure 9. Column Detail

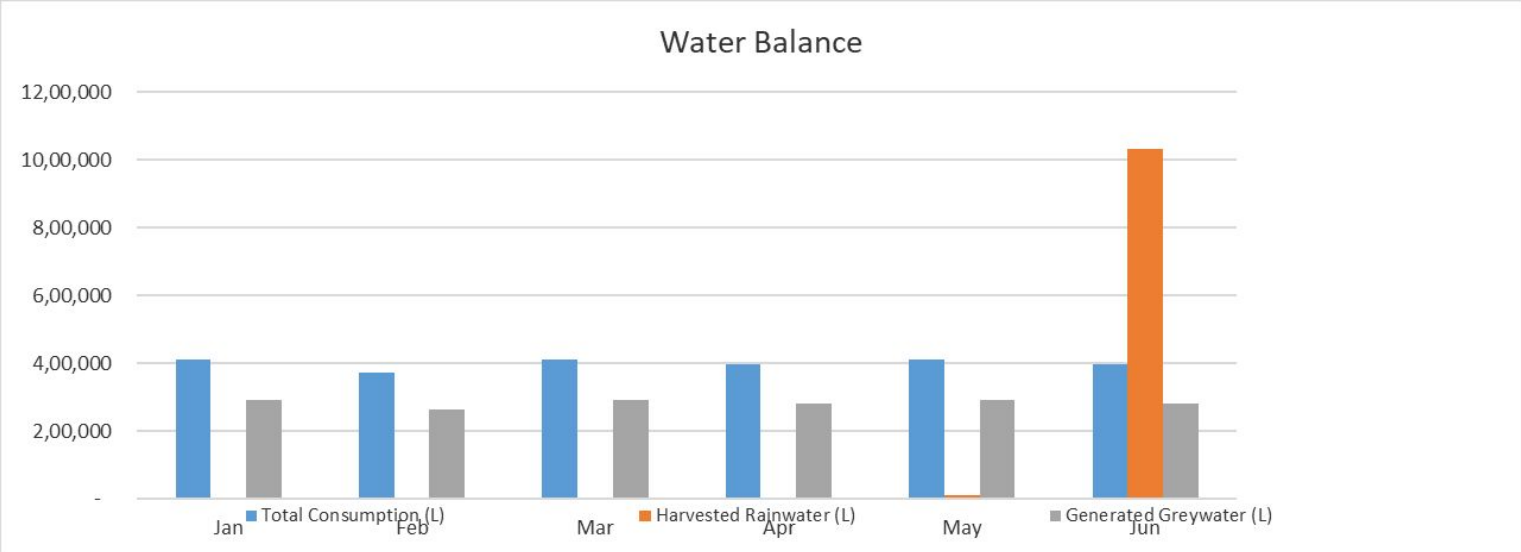


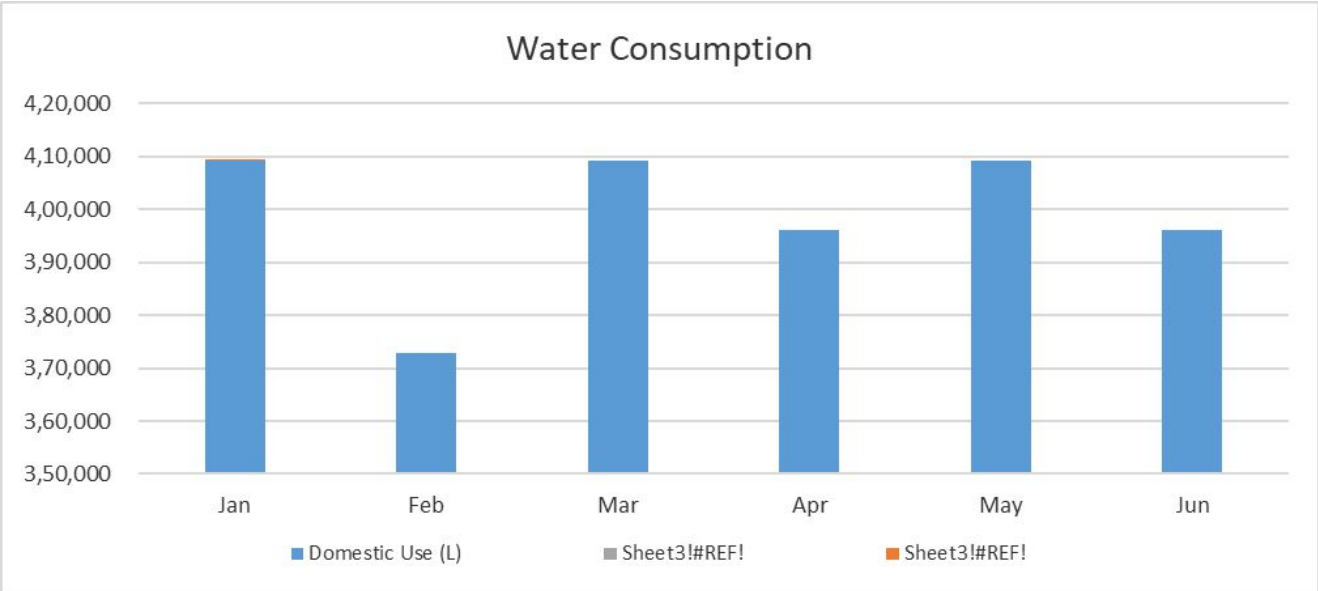
- **Foundation**- Each module is supported by Concrete slab of 250mm x 250mm x 500mm.
- **Column** - Every unit stand on an independent lightweight structural framework made of Mild steel. Ms hollow box section of size 50mm x 50mm x 2mm
- **Flooring**- Recycled plastic waste panels are used which is resistant to termite, rust and fire.
- **Metal Bracing** to withstand lateral shockwaves of earthquake.
- **Wall**- Recycled plastic waste panels are used for walls protecting the interior from heat as it absorbs heat. Water absorption value is as low as 0.25 %
- **Roof**- Eco roof sheets are installed as a roofing material that is resistant to temperature, moisture, fungus and possess high durability.

Input Parameters	Units	Proposed Design Values
General		
Building Area	m²	4960
Conditioned Area	m²	-
Electricity Rate	INR/kWh	4.57
Natural Gas Rate	INR/GJ	Not Applicable
Building Occupancy Hours	-	Example: 5pm - 8am
Average Occupant Density	m² / person	0.2
Internal Loads		
Interior Average Lighting Power Density	W/m²	1.5
List of Lighting Controls	-	-
Average Equipment Power Density	W/m²	3
Minimum OA Ventilation (Building Average)	l/sec.m²	0.3
Envelope		
Roof Assembly U value	W/m².K	0.6
Roof Assembly SRI		86
Average Wall Assembly U value	W/m².K	0.6
Window to Wall Area Ratio (WWR)	%	16
Windows U value	W/m².K	1.2
Windows SHGC		0.3
Windows VLT		0.4
Infiltration Rate	ac/h	0.35
Describe Exterior Shading Devices		-
HVAC System		
HVAC System Type and Description	-	-
Describe Mixed mode strategy in operation/controls of AC and windows	-	-
Heating Source	-	-
Heating Capacity	kW	-
Heating COP		-
Cooling Source	-	-
Cooling Capacity	kW	-
Cooling COP		-
Operation Hours		-
Heating Set Point	°C	-
Cooling Set Point	°C	-
Relative Humidity Setpoint		-

Service Hot Water			
SHW Type and Description		-	If Applicable
Output Parameters	**Units**	**Proposed Design Values**	
Proposed EUI (Total)	kWh/m²/ yr	13.1	
EUI Breakdown by End Use			
Heating	kWh/m²/ yr	-	
Cooling	kWh/m²/ yr	-	
Fans	kWh/m²/ yr	1.65	
Pumps	kWh/m²/ yr	3.71	
Heat Rejection	kWh/m²/ yr	-	
Service Hot Water	kWh/m²/ yr	-	
Lighting	kWh/m²/ yr	0.51	
Equipment	kWh/m²/ yr	5.16	
Miscellaneous	kWh/m²/ yr	2.18	
Total Envelope Heat Gain (Peak)	W/m²		
Cooling Load of Conditioned Area	SF/ Tr	-	
Building Electric (Peak)	W/m²		
Annual Operating Energy Cost	INR/m²		
Annual Unmet Hours	-	-	
Cooling Capacity	Tr	-	
Annual Hours of Comfort without Air Conditioning		3554	
Monthly Energy Performance		Generation	Consumption
Jan	kWh	553	
Feb	kWh	535	
Mar	kWh	611	
Apr	kWh	583	
May	kWh	583	
Jun	kWh	450	
Jul	kWh	391	
Aug	kWh	359	
Sep	kWh	451	
Oct	kWh	557	
Nov	kWh	515	
Dec	kWh	512	

		Consumption		Water sources					
Month	Days in month	Domestic Use (L)	Total Consumption (L)	Effective rain (mm)	Rainwater	Generated Greywater (L)	Filtered Greywater (L)	Blackwater (L)	Total Stored
Jul	31	4,09,200	4,09,200	409195	1745865	2,90,532	2,17,899	1,18,668	1554564
Aug	31	4,09,200	4,09,200	409195	1245415	2,90,532	2,17,899	1,18,668	1054114
Sep	30	3,96,000	3,96,000	395995	785576	2,81,160	2,10,870	1,14,840	600446
Oct	31	4,09,200	4,09,200	409195	93914	2,90,532	2,17,899	1,18,668	0
Nov	30	3,96,000	3,96,000	395995	33843	2,81,160	2,10,870	1,14,840	0
Dec	31	4,09,200	4,09,200	409195	0	2,90,532	2,17,899	1,18,668	0
Jan	31	4,09,200	4,09,200	409195	0	2,90,532	2,17,899	1,18,668	0
Feb	28	3,72,900	3,72,900	372895	0	2,64,759	1,98,569	1,08,141	0
Mar	31	4,09,200	4,09,200	409195	0	2,90,532	2,17,899	1,18,668	0
Apr	30	3,96,000	3,96,000	395995	0	2,81,160	2,10,870	1,14,840	0
May	31	4,09,200	4,09,200	409195	9730	2,90,532	2,17,899	1,18,668	0
Jun	30	3,96,000	3,96,000	395995	1033475	2,81,160	2,10,870	1,14,840	848345
Total		48,21,300	4821300		4947817	34,23,123	25,67,342	13,98,177	40,57,469





Project Summary

Project Project Information

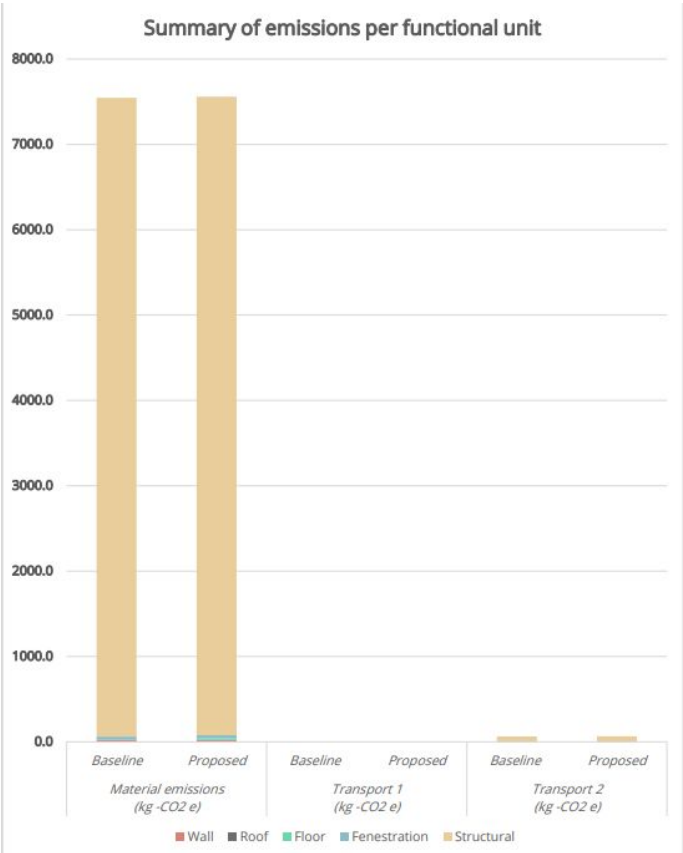
Team:	NOVA		
Division:		**Land Cost:**	on lease
Site Area (sqm)	8,000	**City:**	Tapi
Built-up Area (BUA) (sqm)	4,960	**State:**	Gujrat
Ground Coverage (Plinth Area) (sqm)	4,960		

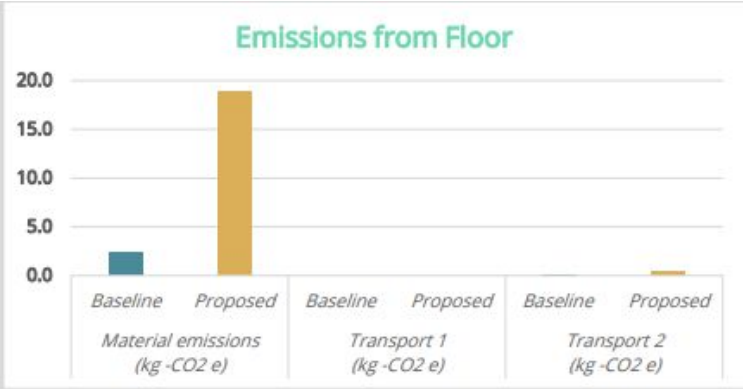
Project Summary

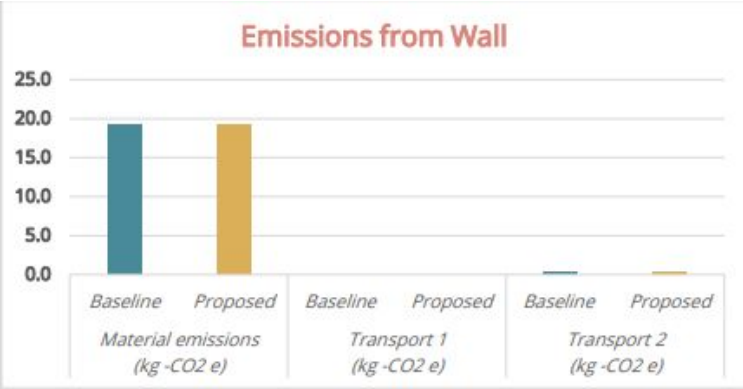
S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount in Million INR	%	Amount (INR per sqm)	Amount	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased by the Project Partner	on lease	#REF!	#REF!	0.00	0.0%	#REF!
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	#REF!	#REF!	#REF!	2704220.00	33.10%	#REF!
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	#REF!	#REF!	#REF!	539800.00	6.6%	#REF!
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	#REF!	#REF!	#REF!	2279200.00	28.0%	#REF!
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	#REF!	#REF!	#REF!	2222800.00	27.2%	#REF!
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	#REF!	#REF!	#REF!	0.00	0.0%	#REF!
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	#REF!	5.0%	#REF!	387301.00	5.0%	#REF!
	TOTAL HARD COST		**#REF!**	**#REF!**	**#REF!**	**8133321.00**	**100.0%**	**#REF!**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	10.00	#REF!	#REF!	10.00	#REF!	#REF!
9	Consultants	Consultant fees on a typical Project	10.00	#REF!	#REF!	10.00	#REF!	#REF!
10	Interest During Construction	Interest paid on loans related to the project during construction	3.75	#REF!	#REF!	2.21	#REF!	#REF!
	TOTAL SOFT COST		**23.75**	**#REF!**	**#REF!**	**22.21**	**#REF!**	**#REF!**
	TOTAL PROJECT COST		**#REF!**	**#REF!**	**#REF!**	**8133343.21**	**#REF!**	**#REF!**

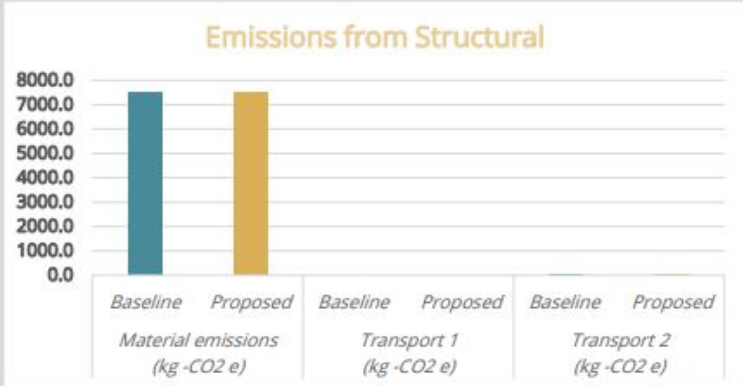
System Type	Baseline			
	Material emissions ($kg\text{-}CO_2\ e$)	Transport 1 ($kg\text{-}CO_2\ e$)	Transport 2 ($kg\text{-}CO_2\ e$)	Total ($kg\text{-}CO_2\ e$)
Wall	19.2	0.0	0.4	19.6
Roof	3.0	0.0	0.1	3.0
Floor	2.5	0.0	0.1	2.5
Fenestration	35.7	0.0	0.4	36.1
Structural	7485.5	0.0	63.3	7548.7
			Grand Total emissions per functional unit ($kg\text{-}CO_2\ e$)	7610.0

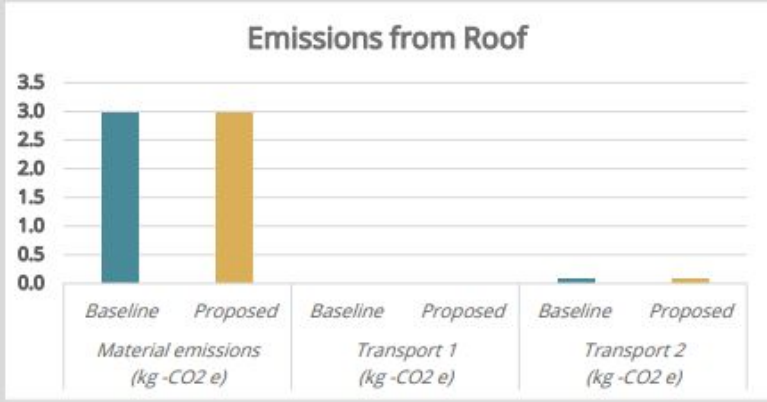
Proposed			
Material emissions ($kg\text{-}CO_2\ e$)	Transport 1 ($kg\text{-}CO_2\ e$)	Transport 2 ($kg\text{-}CO_2\ e$)	Total ($kg\text{-}CO_2\ e$)
19.2	0.0	0.4	19.6
3.0	0.0	0.1	3.0
19.0	0.0	0.5	19.5
35.7	0.0	0.4	36.1
7482.4	0.0	63.3	7545.7
		Grand Total emissions per functional unit ($kg\text{-}CO_2\ e$)	7623.9

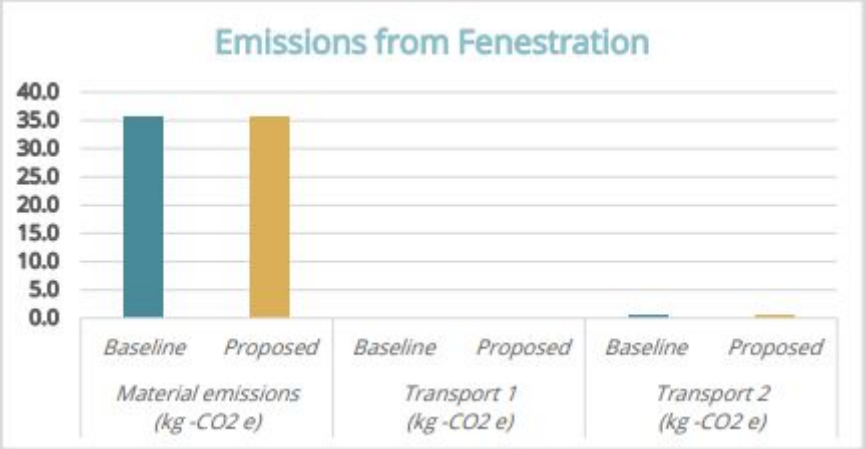



Emissions from Floor
20.0
15.0
10.0
5.0
0.0
Baseline
Proposed
Material emissions (kg -CO2 e)
Transport 1 (kg -CO2 e)
Transport 2 (kg -CO2 e)


Emissions from Wall
25.0
20.0
15.0
10.0
5.0
0.0
Baseline
Proposed
Material emissions (kg -CO2 e)
Transport 1 (kg -CO2 e)
Transport 2 (kg -CO2 e)


Emissions from Structural
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
Baseline
Proposed
Material emissions (kg -CO2 e)
Transport 1 (kg -CO2 e)
Transport 2 (kg -CO2 e)


Emissions from Roof
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Baseline
Proposed
Material emissions (kg -CO2 e)
Transport 1 (kg -CO2 e)
Transport 2 (kg -CO2 e)


Emissions from Fenestration
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Baseline
Proposed
Material emissions (kg -CO2 e)
Transport 1 (kg -CO2 e)
Transport 2 (kg -CO2 e)

Larsen & Toubro Limited
L&T Construction
TAPI KARJAN LIS, Songadh

LARSEN & TOUBRO

Date: 04.10.2022

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization L&T WET IC: TAPI KARJAN LIS, has provided information about our Construction Workman Habitat to the participating team led by Jamia Millia Islamia, so that their team NOVA may use this information for their Solar Decathlon India 2022-23 Challenge entry.

As a Project Partner to this team for the Solar Decathlon India 2022-23 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, resilient and affordable solution this student team proposes and the innovation that results from this.

We would like to have a representative from our organization to attend the Design Challenge Finals event in April/May, if this team is selected for the finals.

We do not want our organization's logo to be displayed on the Solar Decathlon India website, recognizing us as one of the Project Partners for the 2022-23 Challenge.

With warm regards,

PDJoshi

Name of Representative: Padmadip Joshi

Designation: Planning Engineer

Email: padmadip.joshi@gmail.com

Phone: 9924527471

Ahmedabad Segment Office:1009-16, 10th Floor Sakar II, Near Ellis Bridge, Ashram Road, Ahmedabad 380006
Headquarters: Mount Poonamallee Road, Manapakkam, P.B. No. 979, Chennai - 600 089. INDIA
Registered Office: L&T House, N. M. Marg, Ballard Estate, Mumbai - 400 001. INDIA
Licence No.: CIN - L99999MH1946PLC004768

L&T Construction - Water & Effluent Treatment is a brand of Larsen & Toubro Limited

RicronPanels
MANUFACTURERS OF REGENERATED PLASTIC SHEETS

Certified Green Product

Date: 14/04/2023

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organisation, RICRON PANELS PRIVATE LIMITED (Formerly known as DEEYA PANEL PRODUCTS PRIVATE LIMITED), is collaborating with the participating team lead by JAMIA MILLIA ISLAMIA (A Central University by an Act of Parliament) Faculty of Architecture & Ekistics on an On-site Construction Worker Housing contributing to real projects for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be in form of us providing them with the technical details of the RICRON PANELS developed by us to use in the innovation for their design.

We would like have a representative from our organisation attend the Design Challenge Finals event in April/May, if this team is selected for the Finals.

We would like our organisation's logo to be displayed on the Solar Decathlon India website, recognising us as one of the Industry Partners for the 2022-23 competition.

With warm regards,
RICRON PANELS PRIVATE LIMITED

AUTHORISED SIGNATORY

RICRON PANELS PRIVATE LIMITED Ankleshwar

RICRON PANELS PRIVATE LIMITED
(Formerly known as "Deeya Panel Products Pvt Ltd")

6108/6109 G.I.D.C., Ankleshwar - 393002, Gujarat info@ricron.com www.ricron.com