Final Design
report

April 2022

On-site construction worker housing

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1.0 Executive summary

The students of Team Samanvit are a mix of architecture and engineering majors (civil). The team has partnered with Apeejay Logistics to strive for net zero water, net zero energy, resilient and affordable housing for construction workers by adopting Duffy's six shearing layers. The IRR calculated has a period of **4 years** along with a profit of **19 %** to the project partner.

Problems	Solutions	Potential		
		Economic	Social	Environmental
Production of raw materials	•Use of GFRG panels and FRP C channels for joinery •Use of joints •Use of suspended furniture to reduce dead load on structure	Considering the life span, it is cost efficient	Employing labors using local materials	Promoting healthier environment by recycling plastic waste
Manufacture	Use of lightweight materials, durable and stackable, tyre foundation, steel corrugated sheets	Lightweight materials are used, hence can be transported easily	Convectional techniques can help to employ local labors.	Reusing waste like tyre in the foundation and Zero waste generation on site
Transport	Transportation through railways is cost effective	Multiple units can be transported at once	Reduces road trafficking	Less transportation is required
Construction	Housing units are scalable and deployable which can be assembled easily	As the structure is dismantlable it can be used multiple times	Relaxation time increases as the construction time reduces	Ecofriendly construction methods to reduce environmental impact
Maintenance	Use of dry constructions that allow refurbishment with nearly zero maintenance	Maintenance is very low	Less maintenance, more labor productivity	Low VOC adhesives and sealants to maintain Good IAQ
Disassembly	Housing units are modular which can be disassembled easily	The panels can be readily fixed or improved, extending their useful life.	Less social hindrance due to quick installation	Multiple usage cycles before it is discarded
Waste management	•Use of two ARTI biogas digesters to disintegrate kitchen & sewage waste. •Use of concealed pipelines within joinery of FRP panels •Use of greywater conditioning unit & adopting low flow plumbing fixtures to reduce water consumed by flushing	Highly lucrative	Improves standard of living	Reduces environmental pollution by reusing and treating the waste
Thermal/ visual comfort	Through Energy simulation	Optimal design solutions that reduces operative cost	Improves health and comfort for workers	Consideration of environmental factor to enhance living conditions

Table 1.1: Overview of design process

2.0 Team Introduction

Team Name: **Samanvit**

Institution Name: **Manipal School of Architecture and Planning**

Division: **Onsite Construction Worker Housing**

2.1 Team members

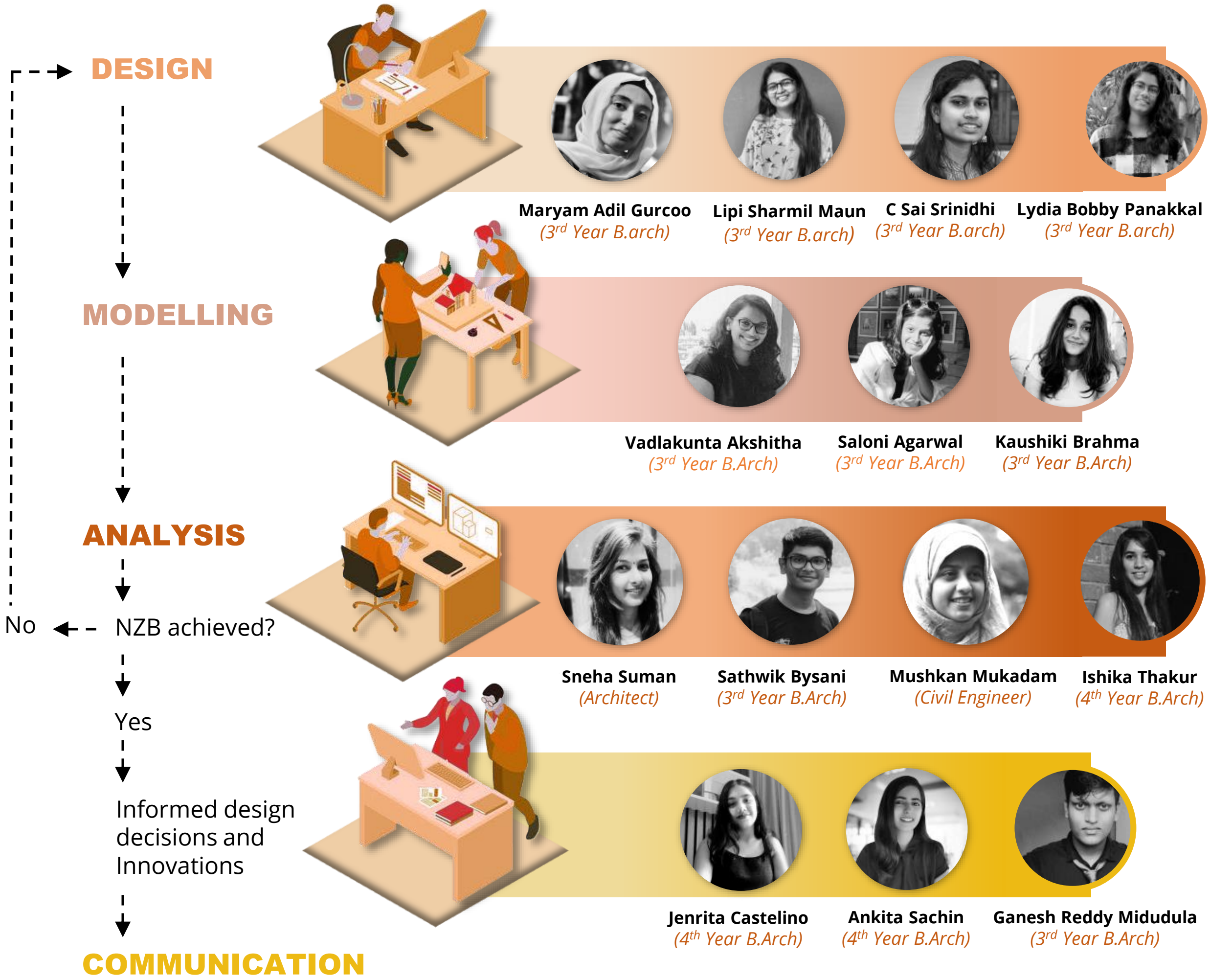


Figure 2.1: Team members

2.2 Approach

With the vision to design sustainable built environment contributing to circularity, we the fourteen members from architecture and civil background, possessing passion in design, modelling, analysis and communication have come together as 'Team Samanvit'.

The Design group task is to formulate the Net Zero Building (NZB) by making integrated and informed design decisions in six shearing layers – Site, Structure, Skin, Space, Services and Stuff.

The Modelling and Analysis groups model, simulate and evaluate the design concepts put forth by the Design group, look into affordability, health and wellbeing, resiliency etc.

The informed design decisions and innovations contributing to achieve NZB are formatted into reports, presentations, movies, and other knowledge products by Communications group. The groups may be diverged during activities but converge regularly to discuss and define the final outputs.

2.3 Background of Lead Institution

Manipal School of Architecture and Planning (MSAP) established in 1978, has a pioneering legacy of more than 40 years that offers unique and essential programs in the domains of architecture and design in the country. It strives to establish academic and professional excellence in architecture and design with state-of-the-art facilities and infrastructure. The dedicated and experienced faculty encourage student centric practices in theoretical as well as practical problem-solving and hone their design thinking.

2.4 Faculty Lead and Advisors

Ar. Naga Venkata Sai Kumar Manapragada *(Faculty Lead)*

B.Arch., MS by Research |Assistant Professor | MSAP Bioincubator Coordinator | MSAP, MAHE Karnataka | Co-chair | Workgroup – 3 | Cool Building Solutions Collaborative | LBNL, USA

Ratna Sravya
(Faculty Advisor)
B.Arch., M.Arch.
Assistant Professor
MSAP, MAHE, Karnataka

Vaibhav Jain
(Faculty Advisor)
B.Arch., MS
Assistant Professor
MSAP, MAHE, Karnataka

Amarnath Sharma
(Faculty Advisor)
B.Arch., M.Arch
Assistant Professor- Sr. scale
MSAP, MAHE, Karnataka

2.5 Industry Partner

Akshita Infra

Street Number 2, Sri Nagar Colony, Kamalapuri Colony, Banjara Hills, Hyderabad, Telangana 500042

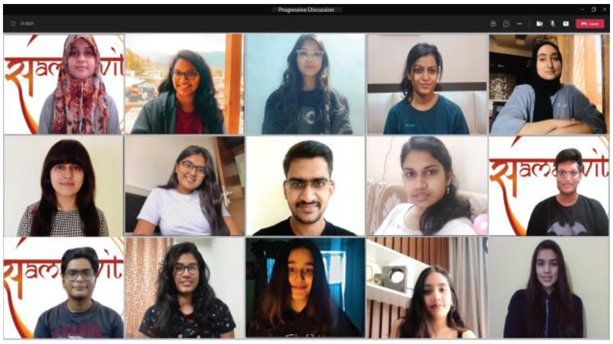
2.6 Design management process

The team was divided into four categories – analysis, modelling, design and graphics. The design approach started with the analysis of factors for a sustainable built environment, whose results were adopted by the design team and a suitable solution was derived. Models were developed for analysis and representation purposes. The communication team aided in conveying the information through infographics, aesthetics and composition and the team leader helped in coordinating between the different groups by holding regular meetings and organising the data.

Shearing layers	Design	Modelling	Analysis	Communication
1. Site	Aspect ratio-1:2,orientation – 0 degree N	Block models of the structure was made for analysis	Orientation, aspect ratios and design recommendation ideas as per climatic analysis	Clarity of location of site, composition of site and climate analysis work
2. Structure	Plinth beams- FRP composite C channels, columns- C channel bolted, prefabricated trusses, tyre foundation	Diagram of the proposed skeletal	Soil analysis for the foundation and structural stability	Visual representation of the assembly process
3. Skin	PV panels on prefabricated truss system, corrugated metal sheet, FRP skeletal frame, fenestrations, GRFG panels for flooring	Exploded view of the dwelling unit	Comparison and material selection	3d color and representation correction
4. Services	Duplex solar panel, rainwater harvesting through pits and pop up filter, grey water recycling system, ARTI biogas plant, bioclean biodigester, VAM	Block model for stimulations	Sun path analysis, rainwater harvesting potential, water calculation, utilization of the waste generated on site	Explanatory diagrams
5. Space	Zoning and development of layout	2d diagrams and exploded 3d views	Comparison of the space requirements with the standards	Enhancement of layout and views
6. Stuff	Flexible, modular and convertible furniture	3d of furniture	Reducing dead load on structure	Composition of sheet

Table 2.1 : Design management process – Division of categories

2.7 Timeline



The team interacted periodically along with the mentors via MS Teams and a one drive folder was made for regular update of work. Common Microsoft links were created for groups to work simultaneously. The teams interacted with each other to produce different versions of design constantly updating and improvising each time. Meetings with the industry partner were conducted to grasp concepts for the design enhancement.

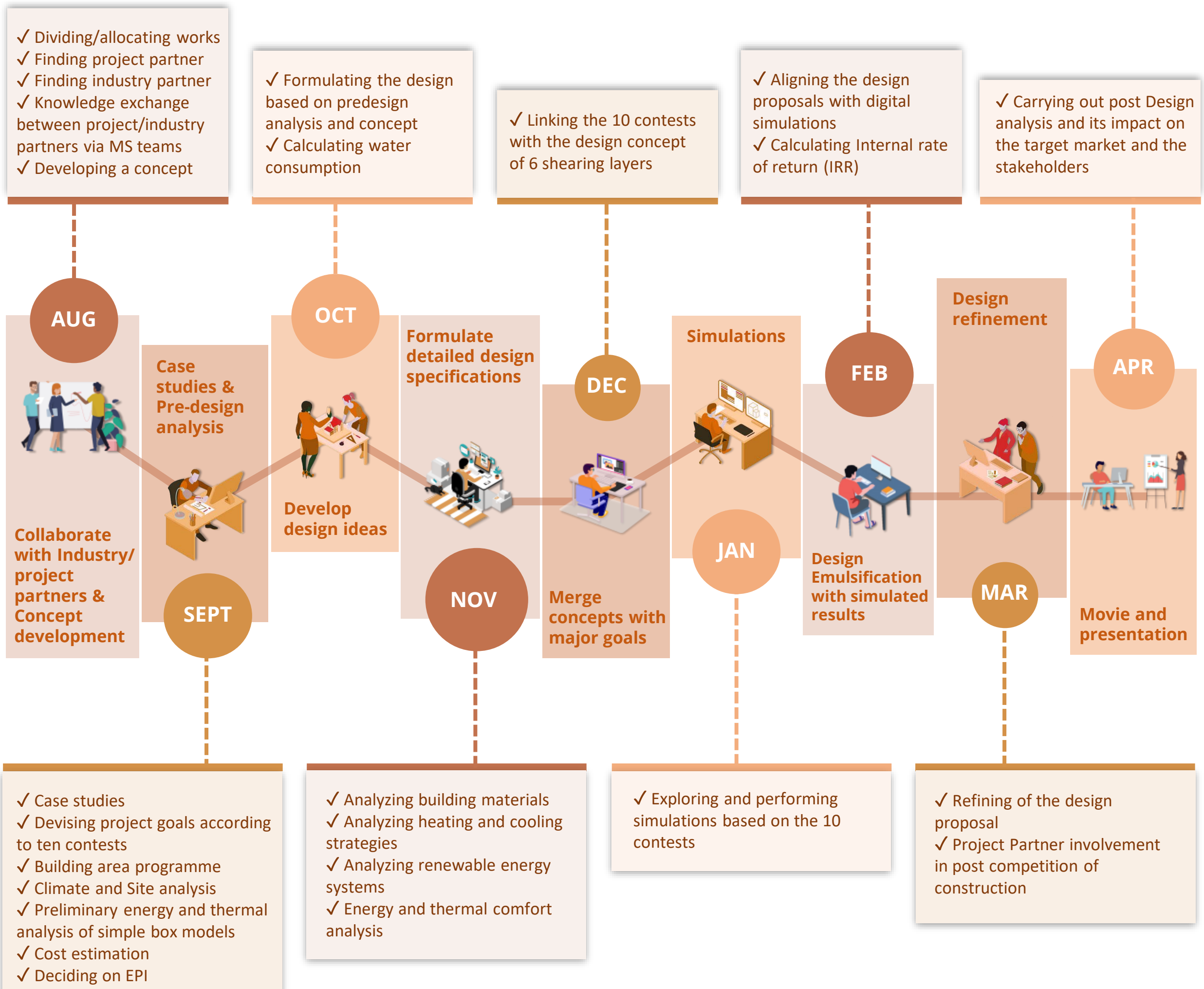


Figure 2.2 : Design process timeline

2.8 Applications used

Autocad Rhinoceros Design Builder Grasshopper Sketchup Photoshop Revit Adobe Illustrator PowerPoint Excel RETScreen

3.0 Project Background

Project Name : SaHai- Shiftable Habitat

3.1 Project Partner

Apeejay Global Industrial And Logistic Park Limited

23/5 milestone, Delhi Mathura road, Ballabhgarh, Faridabad – 121004,

The company is a warehousing and industrial park that offers new-age efficiencies and best in class infrastructure and resources. Samanvit has been working closely with Mr. Aritra Kar, Manager Of Projects.

3.2 Brief Description Of The Project

During the pandemic, the need to provide an on-site construction worker housing emerged due to reverse migration of construction workers from urban to rural. Provision of habitable onsite construction worker housing has never been the tradition for contractors. The unavailability of construction labor delayed the projects and costed economic losses to the clients and building contractors. The need for modular onsite construction worker housing sprung up with consecutive COVID-19 pandemic waves. One of the similar requirements has also been floated by **Apeejay Global Industrial And Logistic Park Limited.**

3.3 Site context

Nearest **Railway station**

Ballabhgarh railway station is located 1.2 km from the site.

Nearest **Police station**

Ballabhgarh police station is located 0.5 km from the site.

Nearest **Hospital**

Samrat hospital is located 2.9 km from the site.

Nearest **Restaurant**

Corporate kitchen is located 2.2 km from the site.

Nearest **School**

PLD public school is located 1.3 km from the site.

Others

Industrial buildings - JBC pvt. ltd. Ltd. , STL global ltd.

The proposed site is located in Sector 25, Faridabad, India (28°19'24.5"N 77°18'38.4"E).

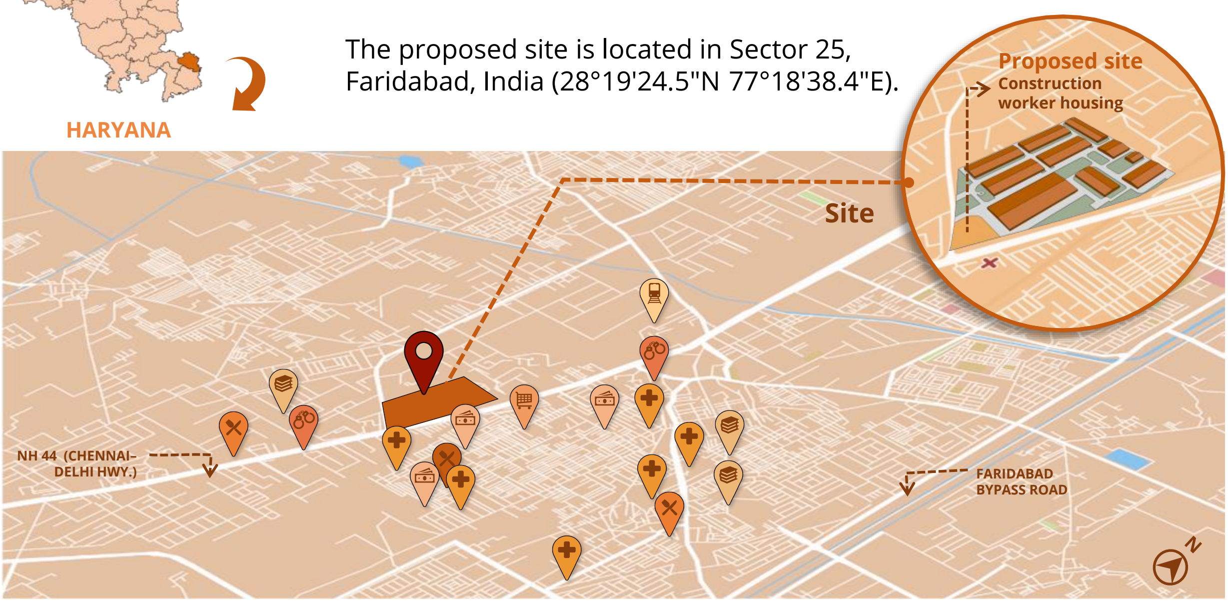


Figure 3.1: Site context map

3.0 Project Background

Total Project Site Area: **339040.10 SQ.M**

Construction Worker Housing Site Area (Excluding Roadways And Construction): **14,305 SQ.M**

Proposed/ Estimated Built-up Area: **1150 SQ.M**
Number of people:**120** Male:**100** Female:**20**
The modular structure can be a build own operate project model in which one builds, owns, and operates or a build own lease project model in which one builds the structure, owns the structure and lease the structure at the end of the lease period.

3.4 Energy Performance Index (EPI) Goal

As there were no EPI benchmarks available for onsite construction worker housing, *the energy monitoring studies* of EWS houses were considered for Business-as-usual (BAU) EPI.

System	BAU EPI	Target EPI
Without HVAC	17.4	8.6

Table 3.1: EPI [in kWh / m^2 / year] Goal

The low BAU EPI includes lot of discomfort hours to the occupants. The proposed design targets Net-Zero EPI without compromising on occupant comfort, health and well-being.
For 50% roof area with 85% inverter efficiency and 15% PV module efficiency, the **101.3 MWh** annual energy generation potential has been observed. Similarly, the **242.5 MWh** annual energy generation potential has been observed for 80% roof area with 95% inverter efficiency and 20% PV module efficiency.

3.5 Construction budget

The baseline budget has been studied from PMAY (Pradhan Mantri Awas Yojana) project developed by INSDAG with single housing unit of 24 SQ.M. The proposed design is modular in nature, whose capital expenditure is expected to be higher than baseline estimate. However, the structure is scalable and relocatable to multiple worksites and thus it only incurs commissioning and logistics cost from the next project to the developer / contractor.

Particulars	Baseline estimate		Proposed design estimate	
	Amount (INR)	%	Amount (INR)	%
Civil works (including painting, false ceiling, doors and windows)	2,79,554	74.1	2,82,105	65
Plumbing services(internal water supply and sanitation)	22,364	5.9	43,400.7	10
Electrical services	22,364	5.9	43,400.7	10
Furnishing	19,569	5.2	13,020.2	3
Contingency	5,591	1.5	21,700.4	5
Total hard cost	3,49,443		4,03,627	
Establishment cost	22,364	5.9	8,680.2	2
Transportation	0	0	21,700.4	5
Interest during construction	5,591	1.5	0	0
Total soft cost	27,955		30,381	
Total project cost per unit house	3,77,398		4,34,008	
Cost / SQ.M	15725		18,084	

Table 3.2: Construction budget

3.6 Special Requirements of the Project Partner

The client is interested in having modular spaces for onsite construction worker housing that can be scalable and deployable based on size and location of the project. Considering the pandemic scenario, natural lighting, and ventilation strategies have been requested for better health and well-being of laborers. Need for the solid waste management - proper disposal, handling, and treatment of the waste types generated in the houses has also been highlighted. Having a low operational cost is key requirement to the project partner.

4.0 Performance Specifications

4.1 Climate Zone

Climatic zone classification	Mean monthly dry bulb temperature	Relative humidity
Composite	13 °C - 29 °C	40 % - 63 %

The comfort band falls between 17.3°C and 33.1°C according to the Indian model for Adaptive comfort Natural Ventilation (IMAC-NV) model for given DBT profile.

4.2 Performance Specification

4.2.1 Envelope

U-value	0.38
VLT	The higher the Visible Transmittance number, the more natural light your window will allow to filter through
COP	3
EER	10.23
SHGC	2.35

Table 4.1: Envelope performance specifications

8.2.2 HVAC

System type	VAM
Type of ventilation	Mixed-mode ventilation (natural ventilation, mechanical ventilation- ceiling fans and exhaust fans in toilets, radiant cooling is used in living areas)
Star rating	★★★★★ ; Higher star rating, better energy efficiency

Table 4.2: HVAC performance specifications

4.2.3 Lighting

LPD				
3.4 W/Sq.m	3.8 W/Sq.m	5.8 W/Sq.m	4.6 W/Sq.m	7.5 W/Sq.m
Tool room	Rest rooms	Dining room	Dorms	Kitchen

Table 4.3: Lighting power density (LPD) of various spatial zones

4.2.4 Electrical

Fixtures control: Lighting controls can help save energy – and money – by automatically turning lights off when they're not needed, by reducing light levels when full brightness isn't necessary, or otherwise controlling the lighting in and around your home. Efficient control systems are required to maximize energy efficiency.

Appliances: Utilization of BEE star rated appliances are preferred to aid in achieving maximum efficiency (Appliances such as - Fan, exhaust, led bulb, tube light, HWU, TV)

4.2.5 Water systems

Rainwater	1056822 litres (generated and treated annually)
System type	Pop-up filter
Treatment	Filtration

Table 4.4: Rainwater system type and treatment

Grey water	2710665 litres (generated and treated annually)
System type	Jal sevak greywater recycling system
Treatment	Filtration and Disinfection

Table 4.5: Grey water system type and treatment

4.2.6 Others

Renewable Energy	
Type	Duplex solar panels- polycrystalline PV SOLAR MANEL
Module efficiency	35%
Specification	300Wp, 24V, 46 Nos

Table 4.6: Renewable energy performance specifications

Bio clean biodigester: Blackwater is collected and passed through the biodigester to generate heat energy which is then used as energy for boiling LiBr solution in the vapor absorption machine which thereby helps in cooling the grey water and passing it on to the radiant cooling panels.

Vapor absorption machine: Using a vapor absorption machine instead of an air conditioner helps us in reusing the waste- water and heat generated by the biodigester. Hence it is an energy-efficient innovation.

5.0 Goals

Contest Area	Goals	Strategies
Energy Performance	Achieve 0 of kwh/m^2/year EPI through on-site renewable and non-renewable system	
	1. With renewables i. Total energy generated = 13873 Kwh ii. Reduction in HVAC load = 40% iii. Reduction in lighting load = 24% 2. Without renewables i. Total energy generated = 56.76kwh ii. Reduction in HVAC load = 4.5% iii. Reduction in lighting load = 55%	1. With renewables i. Using PV/t Grid based energy system to generate energy ii. Using radiant cooling with VAM and biodigester for operation of the building iii. Using lights with higher luminous efficacy 2. Without renewables i. Through Site Orientation of the building with least solar exposure in summer and maximum exposure in winter ii. Using High performance building envelope iii. Aspect ratio and dimensions are chosen to increase the daylight percentage decreasing the lighting load
Water Performance	Reduction in total water consumption demand by 44.46% using low flow fixtures and achieving net zero through RWH, pop-up filter, and grey water recycling system.	
	i. Achieving Net Zero water in total water demand by 44.46% through use of low flow fixtures ii. Reduction in total water demand from the base case by 35.3 % iii. Achieve water demand through rainwater harvesting by 28.05%. iv. Achieve water demand through greywater recycling system by 71.95% v. Percentage reduction from GRIHA benchmark for WPI by 25% from 120 L/person/day to 90 L/person/day.	i. Use of rainwater harvesting, grey water recycling unit and low flow fixtures ii. Installation of pop-up filter for RWH iii. By managing and storing 100% of rainwater harvesting system on rooftop, site and tarped collection pits iv. Recycling of Greywater using grey water conditioning unit.
Waste management	Generate Zero Waste onsite for landfill and incineration by using ARTI biogas digester, Greywater Conditioning and bio clean biodigester	
	i. Disintegrate 9.2 Kg/day of kitchen waste and 7.4kg/day sewage waste to produce biogas ii. 6 LPG cylinders are saved every month iii. Using Greywater Conditioning unit to filter suspended particles and disinfect water iv. Recycle 100% of sewage waste and produce 559 KJ heat per day	i. Using 3 ARTI biogas digesters to disintegrate kitchen and sewage waste. ii. Using concealed pipelines within joinery of FRP panels iii. Using Greywater Conditoning unit and adopting low flow plumbing fixtures to reduce water consumed by flushing
Resilience	Designing a resilient structure using FRP material with 160kN/m compressive strength and 2.1kN/me flexural strength.	
	i. Compressive strength of 160kN/m and flexural strength of 2.1kN/me ii. Achieving 220 Mpa N/mm^2 Yield strength and 500 Mpa N/mm Tensile strength for roof	Using FRP material to increase the strength of the building
Affordability	Achieve minimum percent from Project partner's budget through design and simulation of a prototype with movable logistics of 12-15 hrs and near zero maintenance, operation and life cycle cost	
Innovation	Devise a modular design replicable and deployable in different land forms	
	i. Suspended & expandable furniture to reduce dead load on structure and increase space factor by 30% ii. To improve ROI for construction market iii. Biogas for boiling and VAM for cooling water	i. By providing a rented vs ownership prototype for varied scales of commissioning ii. By reduction of U-value of FRP from 2.83 to 0.37 with the use of cellulose fibre
Health and well being	Maintain indoor environmental quality conditions for nearly 86.2% of occupied hours in the year through energy efficient devices and simulation	
Engineering & operations	Achieve high engineering and envelope performance through structural and energy simulations	
Architectural design	Designing functional spaces achieving daylighting, ventilation by reducing embodied energy	
	i. Achieve 1:294.8 ratio of workers' housing area to built-up area. ii. Ensure daylighting and ventilation through passive design strategies iii. Maximise the use of green and renewable materials to reduce embodied	i. Utilizing night purge ventilation as an effective technique for passive cooling to ventilate the modular living units by cooling the structure's thermal mass at night and hence enable user comfort
Scalability and market potential	Contemplate a business model for onsite construction worker housing feasible for large-scale and small-scale contractors	
	i. To fulfil the doubled demand for buildings projected by 2038 (Building Stock Modelling, 2018) and provide pandemic resilient housing for the required labour force	i. By providing a feasible business model for large-scale and small-scale contractors

Table 5.1: Team goals

6.0 Design Documentation

6.0 Introduction

Concept - Linking ten contests to six shearing layers

Shearing Layers is a concept introduced by Frank Duffy and developed by Steward Brant. Fundamentally, buildings are not static concepts, but rather living entities that interact with a living environment. In the course of time, buildings change and grow - the changes can be due to wear and tear or to the user's fancy, to municipal bylaws, or to human and environmental factors.

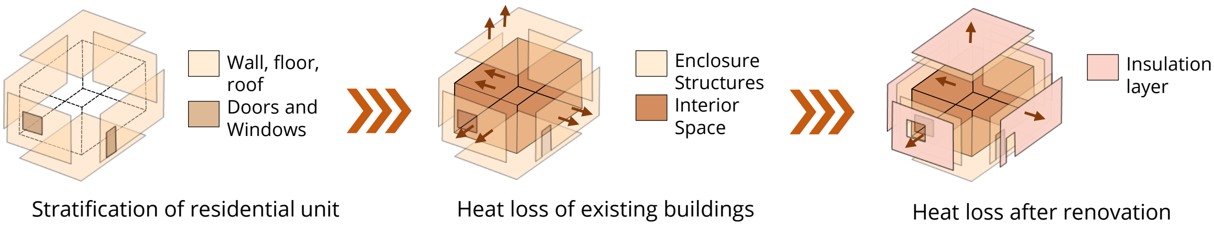


Figure 6.1 : Graphical representation of 6 shearing layers

Duffy's time-layered perspective is fundamental to understanding how buildings behave. Both designs and constructions follow the 6-S sequence precisely. The construction sequence is strictly in order: Site preparation, then foundation and framing of the Structure, followed by Skin to keep out the weather, installation of Services, and finally Space plan. Then the tenants bring their stuff in.

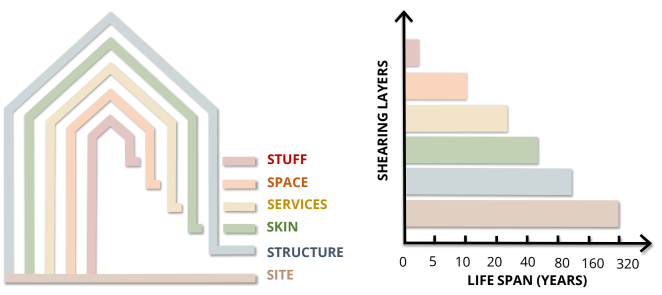


Figure 6.2 : Lifespan of 6 shearing layers

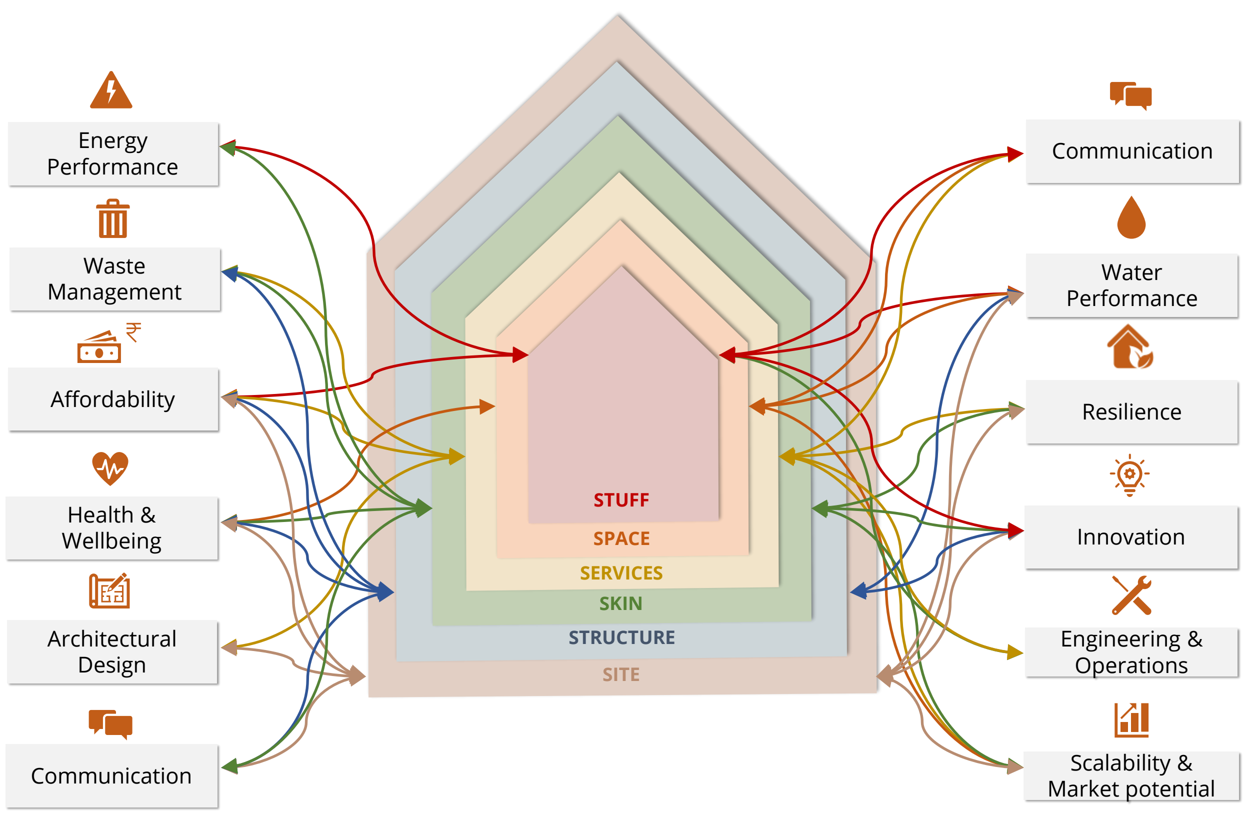


Figure 6.3 : Merging 10 contests with 6 shearing layers

6.0 Design Documentation

6.1 Architectural Design

6.1.1 Informed design decision process

The design follows an informed decision method, which explains why the block placement in the site can accommodate both summer and winter sun exposure. The north-south orientation serves to channel wind flow towards the blocks. The arrangement of units is done in order to link services both within and outside the site.

Ratio	Degree	Summer	Winter	Image of summer and winter sun path & radiation diagram	Effective index (EI)
		Total Radiation	Total Radiation		
1:2	0	1.30E+06	303739.37		1.28E+05

Table 6.1.1: Sun Path and Radiation Analysis

Rainfall analysis is performed after determining the sun path and radiation for the optimal aspect ratio of 1:2 and orientation of 0 degrees, that is north – south orientation with 20% window wall ratio. (Refer to annexure)

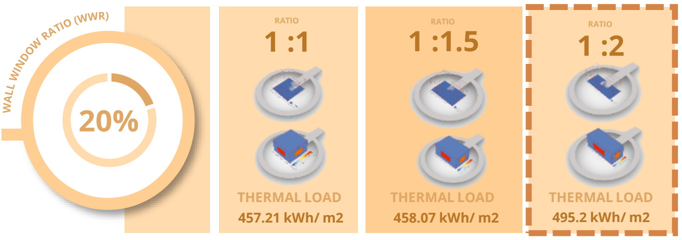


Figure 6.1.1: Window Wall Ratio and Energy Model

Step 1 : Windrose diagram

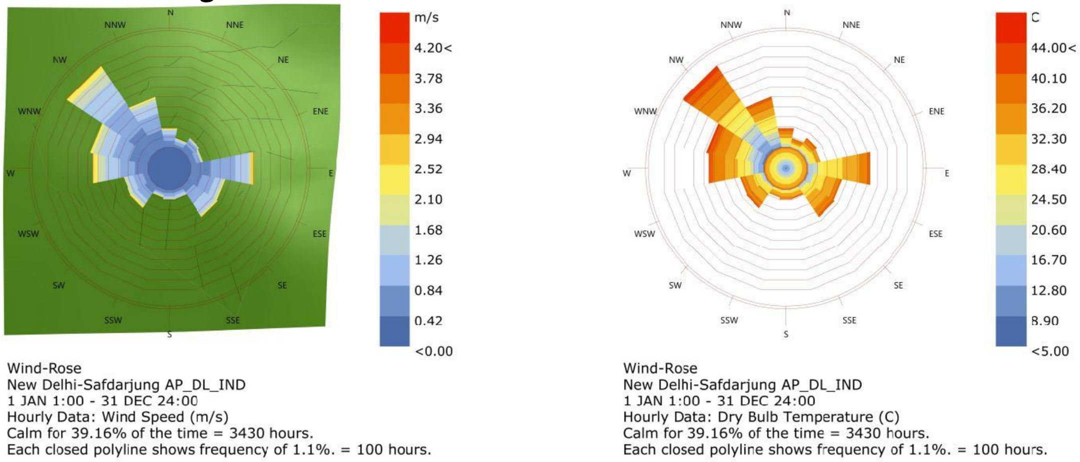


Figure 6.1.2: Windrose Diagram

Windrose is set up in relation to the location to determine the wind's direction, temperature, and speed. The prevailing wind in this case was northwest, thus the building's orientation was set at 45 degrees northwest i.e., north, to get the most wind.

Step 2 : Rainwater analysis

Figure 6.1.3: Rainwater Analysis

The rainwater simulation tool, which analyses a three-dimensional site plan to depict the site's hydrological flow conditions, is used to model rainwater patterns on the terrain. All the patterns are evaluated, and the block placements are chosen to prevent the water from flowing into the blocks. When it comes to water flow, the plinth level of the block is raised, but the water flow is not hindered, and no patterns are changed. The rainwater catchment region is established at the intersection of all the vectors considering the water patterns.

Step 3 : Block placement with respect to rainwater channels

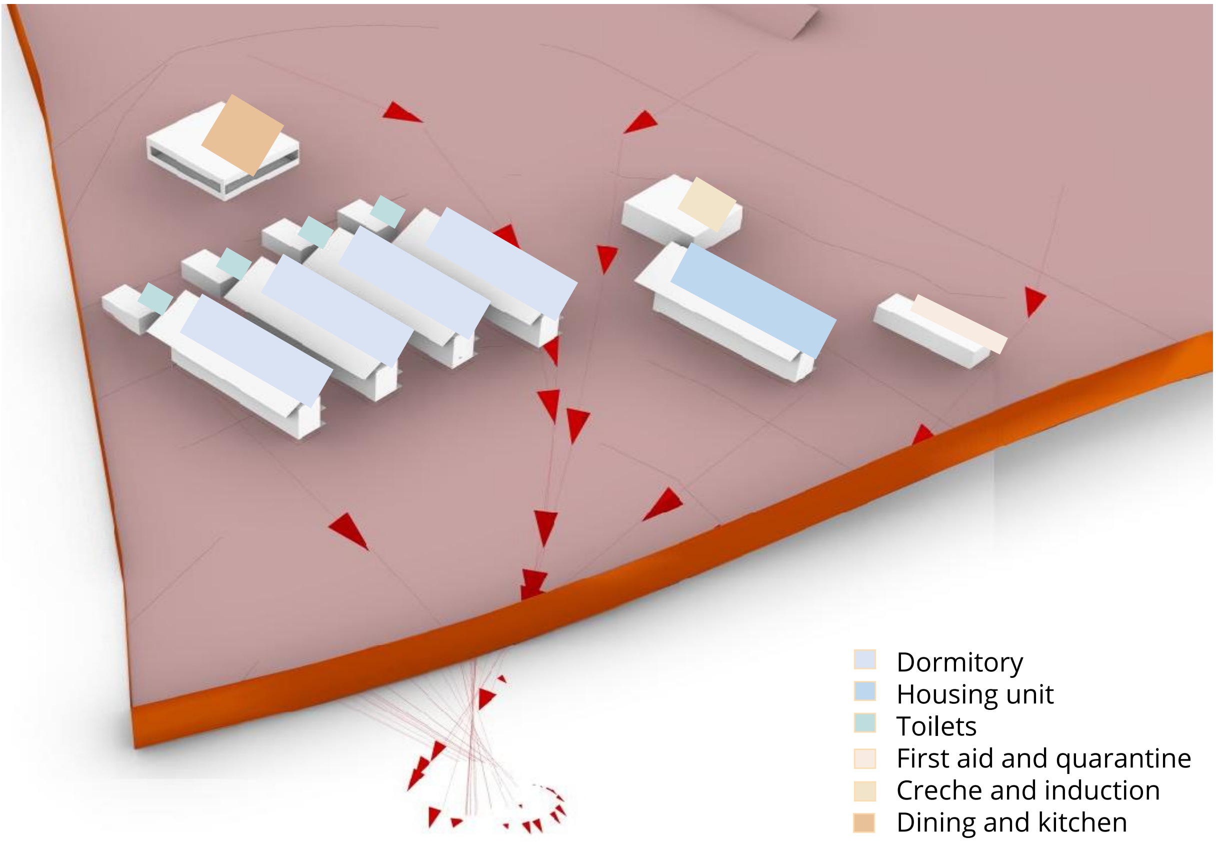


Figure 6.1.4: Block placement with respect to rainwater channels

The blocks are positioned in relation to the rainwater channels so that we do not have to detour from any water channel or experience water coagulation while living.

Step 4 : Radiation analysis

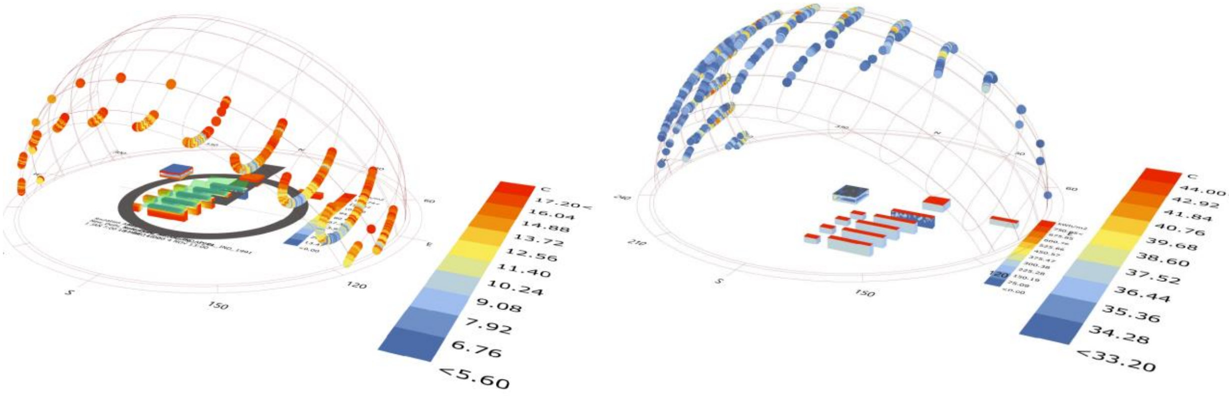


Figure 6.1.5: Radiation Analysis

Radiation analysis was performed to understand the mutual shading effect on the building to reduce summer sun exposure and increase winter sun exposure. Also, the shading effect on context to make surrounding spaces usable.

Overall annual Radiation : 882591.98 kWh/m sq.

6.1.2 Site Plan

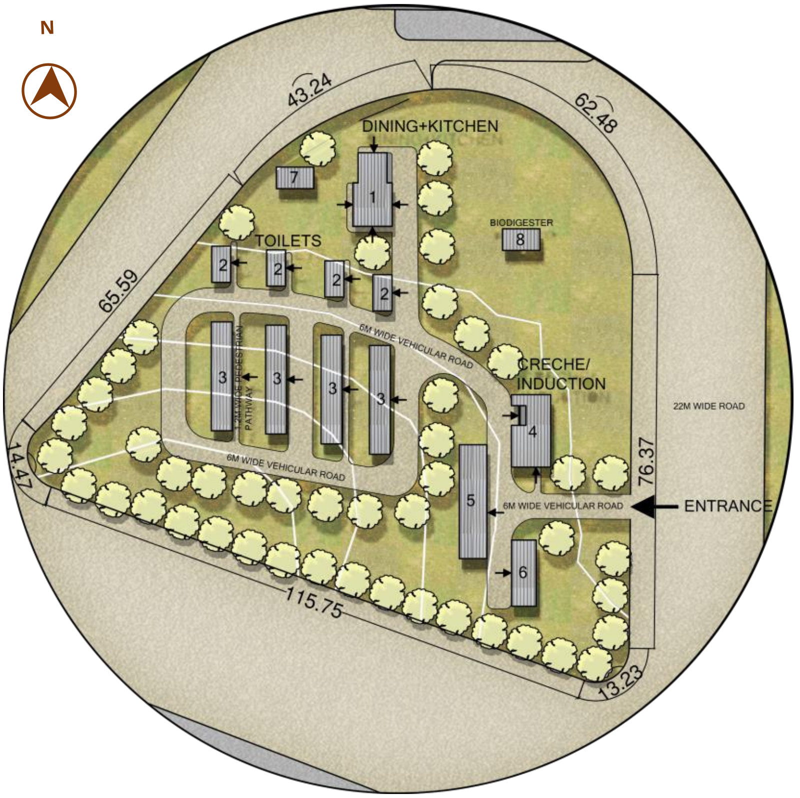


Figure 6.1.6: Site Plan

Legends:
1. Dining+ Kitchen
2. Toilets
3. Dormitory
4. Creche/ Induction
5. Housing
6. Quarantine

Mud road
Vegetation
Grass

All dimensions are in metres

6.1.2 Block Layouts

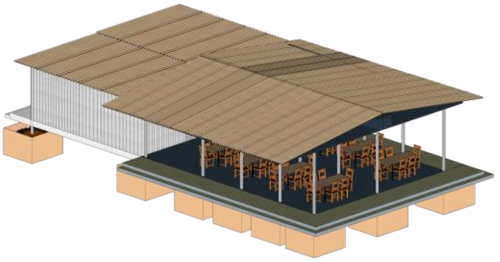


Figure 6.1.7: Dining + Kitchen layout

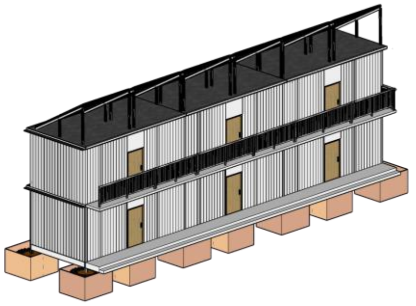


Figure 6.1.8: Dormitory layout

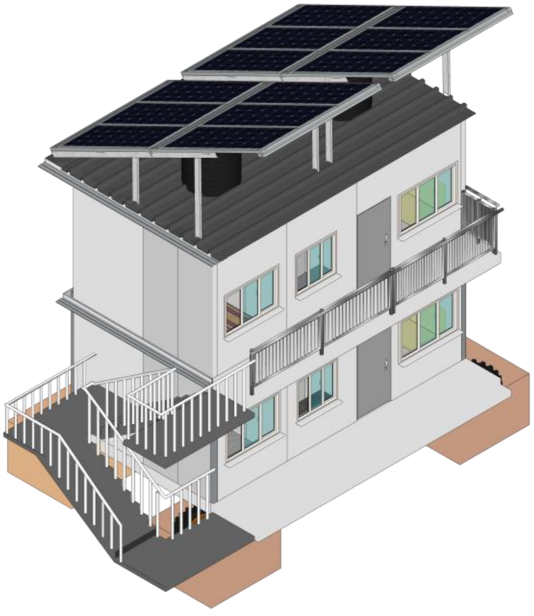


Figure 6.1.9: Housing layout

6.1.3 Floor Plans

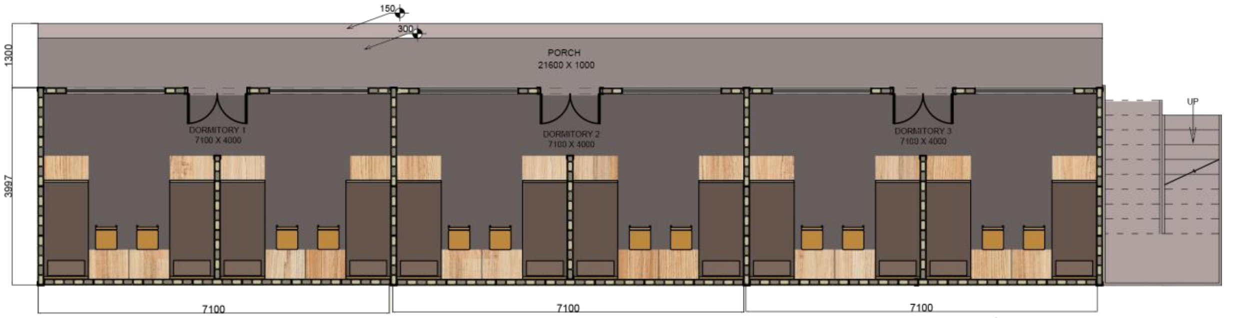


Figure 6.1.9: Dormitory Floor plan

Figure 6.1.10: House Floor plan

Figure 6.1.11: Housing interior view

Refer to annexure for layouts of – Dining + Kitchen, Toilets and quarantine blocks.

6.1.4 Sectional Elevation View

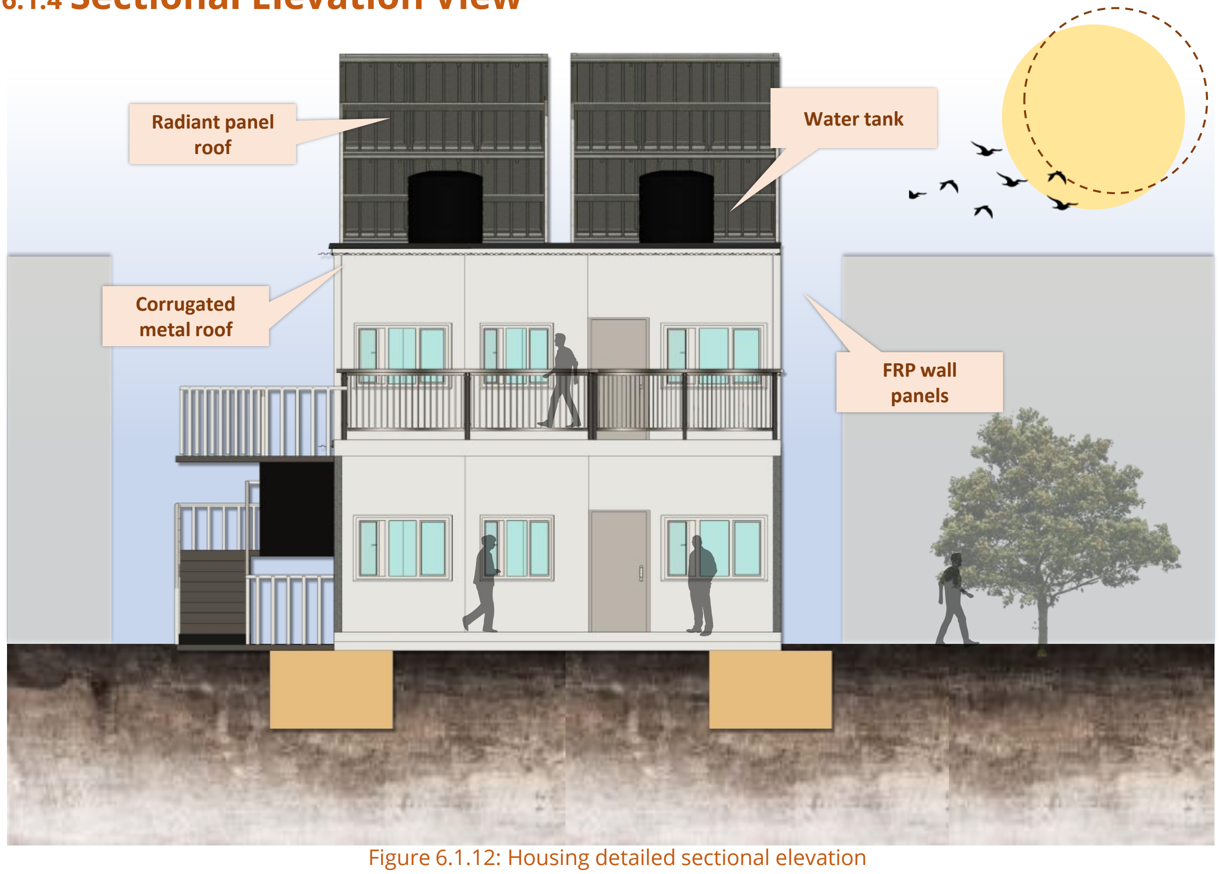


Figure 6.1.12: Housing detailed sectional elevation

6.2 Energy Performance

6.2.1 Business As Usual Case (BAU)

In the Business-as-usual case, we are considering Brick wall, steel and tarpaulin as the building envelope material. The EPI presented is the overall site EPI. The EPI for Tarpaulin achieved is 162.76 kWh/m^2, steel - 126.25 kWh/m^2 and brick-wall - 80.34 kWh/m^2 . Single clear glazing with U-value 5.3 W/m^2.The comparison is shown in figure 10.1.1.

6.2.2 Proposed Case

In the Proposed case, we are considering Glass fiber reinforced gypsum panel (GFRG) of U-value: 0.31 W/m^2 as the building envelope material. The EPI achieved is 26.74 kWh/m^2. Single-layer Low emissivity coating glazing of U-value 3.6 W/m^2.

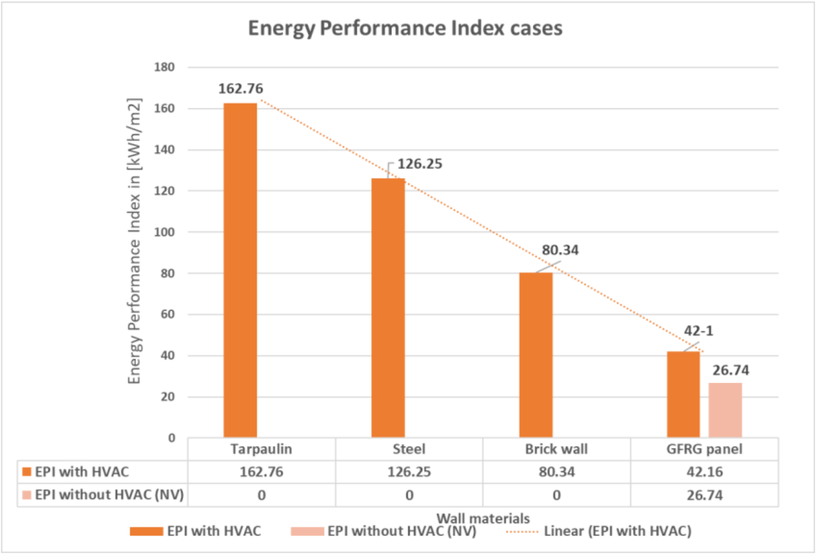


Figure 6.2.1: Comparison between (Base case) Business-as-usual case and proposed case

The Proposed case for the mixed-mode and the naturally ventilated case is shown in figure 10.1.2. Figure 10.1.2(a) is for the overall site naturally ventilated condition with EPI 26.74 kWh/m^2. In figure 10.1.2 (a1) the section of the GFRG panel is shown which Is selected as the proposed case material.

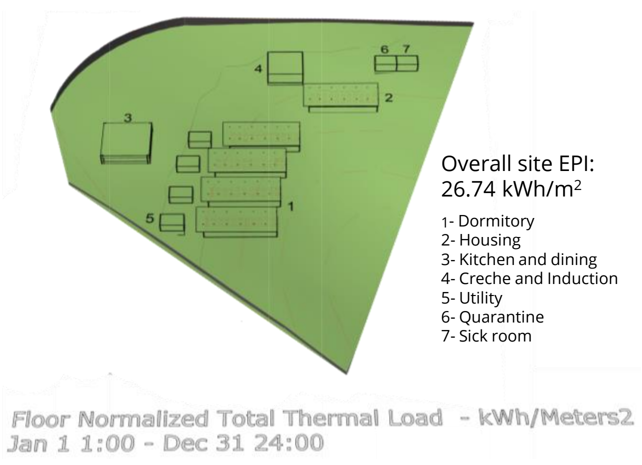


Figure 6.2.2: (a)

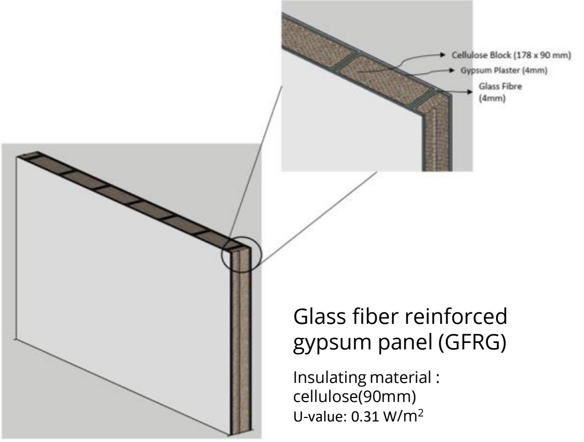


Figure 6.2.2: (a1)

Figure 6.2.2: Site EPI for mixed-mode and naturally ventilated condition

Overall site EPI: 42.1 kWh/m^2

1- Dormitory
2- Housing
3- Kitchen and dining
4- Creche and Induction
5- Utility
6- Quarantine
7- Sick room

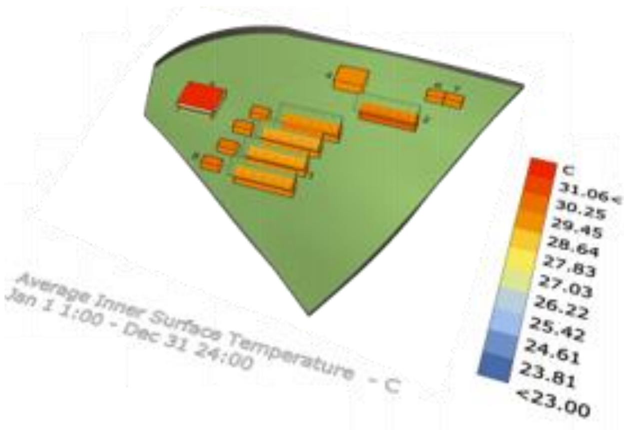


Figure 6.2.2[b) : Surface temperature for naturally ventilated site

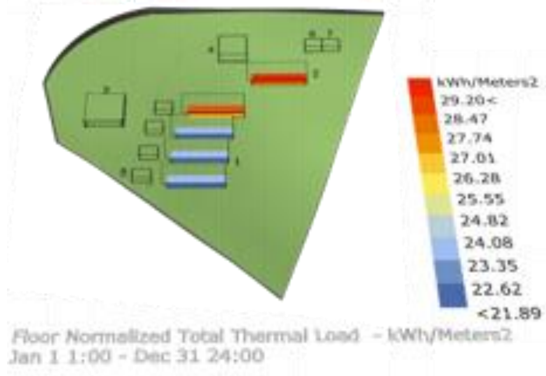


Figure 6.2.2(c): Zone Energy Analysis for mixed-mode ventilated site

Figure 6.2.2: Site EPI for mixed mode and naturally ventilated condition

Figure 10.1.2(b) is the indoor surface temperature for all the blocks that are naturally ventilated, figure 10.1.2(c) is for the mixed-mode ventilated condition in which the dormitory and housing are equipped with radiant panels to provide cooling and heating to the space. Rest other blocks : utility, kitchen, quarantine and sick room, creche and induction blocks are naturally ventilated. The EPI achieved for the overall site for this case is 42.1 kWh/m^2.

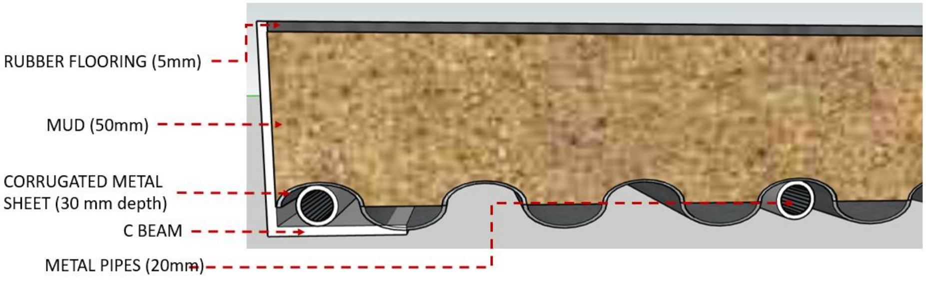


Figure 6.2.3: Cross section of the radiant panel roof

Figure 10.1.3 is the cross-section view of the radiant panels that will provide cooling and heating to the space in the mixed-mode condition. There is corrugated sheet of 7mm thickness, in the depression of the corrugated sheet 20 mm metal pipes are provided through which cooling or heating water passing will help maintain the indoor thermal comfort. The water which is passing through the pipe is cooled due to the vapor absorption machine. Next layer is 50 mm mud layer which is mixed with cow dung to improve the cohesion within the soil and water particles. This will help hold the moisture and keep the mud intact. The topmost layer is the Rubber flooring of 5mm thickness.

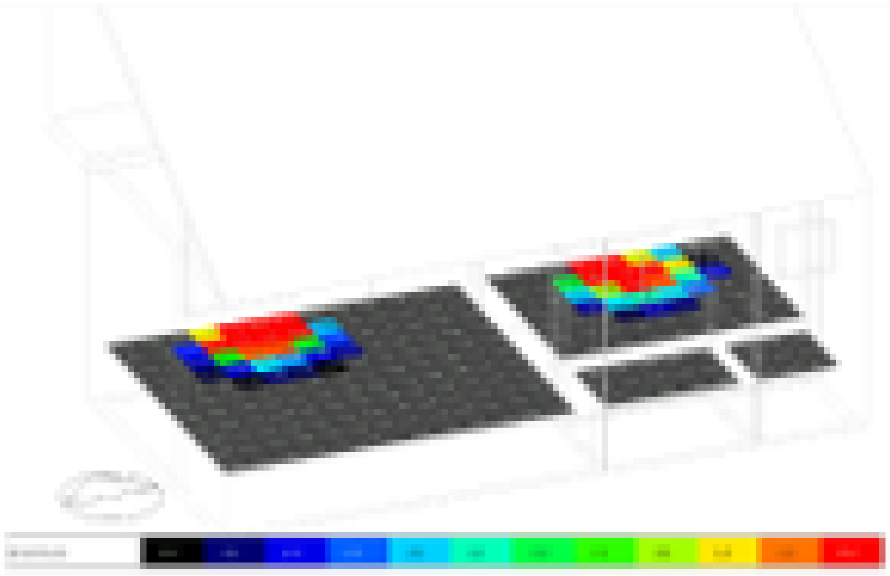


Fig 6.2.4: Plan of Housing Modelled for simulation

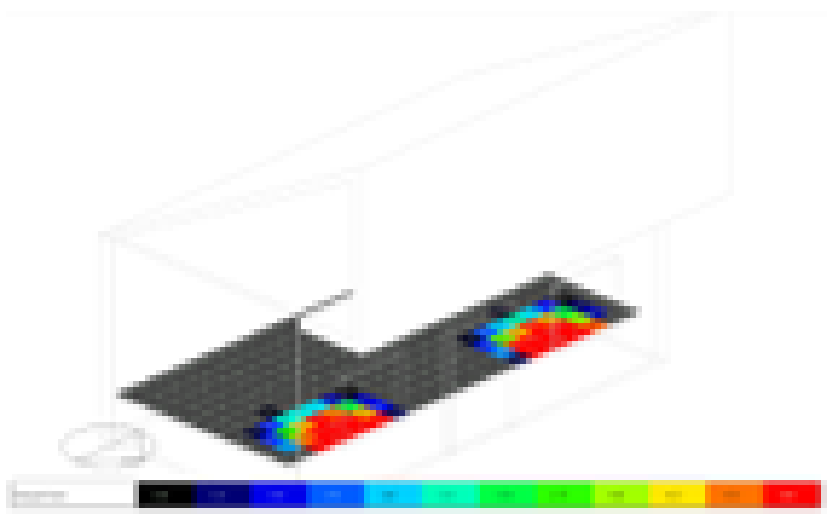


Fig 6.2.5: Daylighting Modelled for Housing Block

The maximum operative temperature is 32 °C which is at the unoccupied hours only, which is 03:00 pm. The Daylighting result in figure 2 and 4 for dormitory and housing block at most extreme day of the year has been simulated for which the daylight factor fall in a range which Is sufficient for the daylight to be admitted into the space for proper visual comfort.

6.0 Design Documentation

6.3 Water Performance

Obtaining net-zero water usage was challenging due to our site's low rainfall and low-cost design. However, using low-flow fixtures, we were able to reduce water usage by 35% over the base case. Additionally, we have used greywater collected on-site to flush, bathe, on our VAM (vapor absorption machine), and for radiant cooling panels.

The systems used to achieve net-zero are-

1. Rainwater harvesting
2. Greywater Recycling system
3. Low-flow fixtures

6.3.1 Net-zero water-cycle and calculations

SOURCE

1. Rain water harvesting
2. Municipal Line

STORAGE

3. Bypass Valve
4. Pop up filter
5. Underground tank
6. Critical storage tank
7. Bio gas
8. Over head tank

USE

11. Housing
12. Dormitory
13. Kitchen and Canteen
14. First Aid and Quarantine
15. Utility

TREATMENT

8. Vardan water filter
9. VAM
10. Inlet valve
17. Outlet valve

REUSE

16. Grey water Recycling

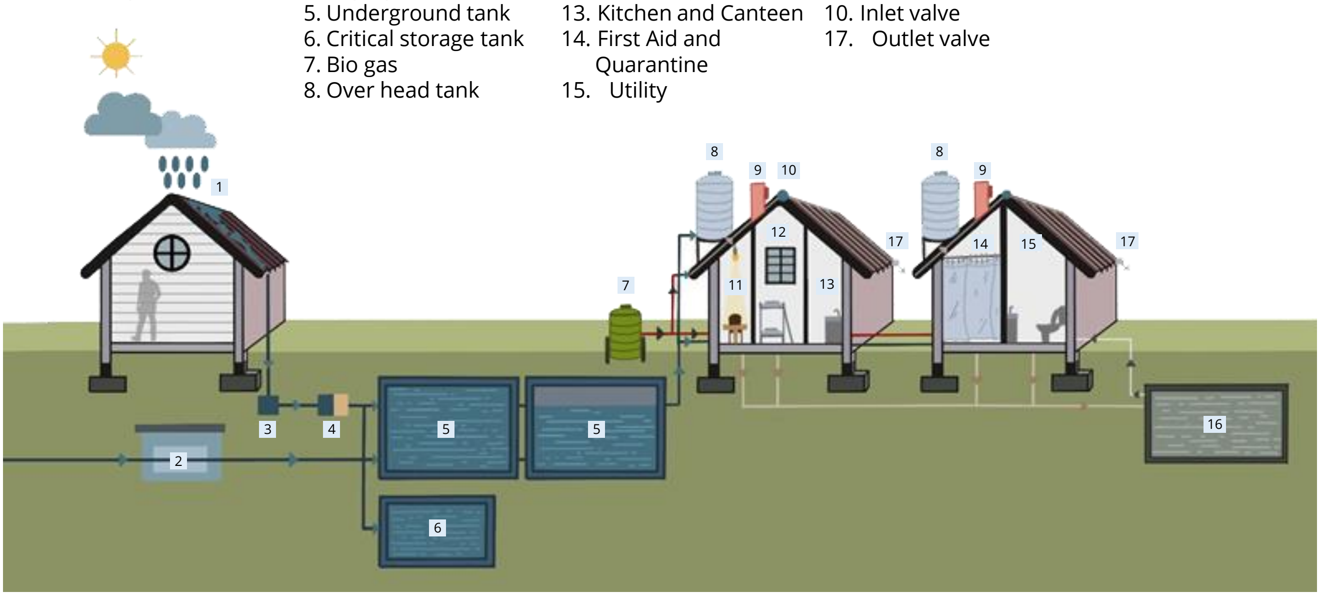


Figure 6.3.1 : Net zero water cycle diagram

Domestic Use	
Use LPD/Head	87.3
Number of people	120
Total LPD	10476

Fire demand	
Quantity of water	1
Quantity of water users	120
Max LPD	120

Cleaning of sanitary blocks	
Quantity of water	3
Quantity of water users	100
Max LPD	300

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing	30%	3143	3,143	
Washing	20%	2095	2,095	
Cleaning house	8%	838	838	
Washing Utensils	16%	1676	1,676	
Others	2%	210	105	105
Drinking	4%	419		419
Cooking	3%	314		314
Toilet Flushing	17%	1781		1,781
Total		**10476**	**7,857**	**2,619**

Table 6.3.1 : Total water consumption

6.0 Design Documentation

Month	Days in month	Consumption				Water sources				Total stored
		Domestic use (L)	Fire demand (L)	Cleaning of sanitary blocks (L)	Total consumption (L)	Municipal water (L)	Rainwater (L)	Greywater (L)	Blackwater (L)	
Aug	31	3,24,756	3,720	9,300	3,37,776	-	380728	2,43,567	81,189	286519
Sep	30	3,14,280	3,600	9,000	3,26,880	-	193430	2,35,710	78,570	388779
Oct	31	3,24,756	3,720	9,300	3,37,776	-	22708	2,43,567	81,189	317278
Nov	30	3,14,280	3,600	9,000	3,26,880	-	1658	2,35,710	78,570	227765
Dec	31	3,24,756	3,720	9,300	3,37,776	-	2818	2,43,567	81,189	136374
Jan	31	3,24,756	3,720	9,300	3,37,776	-	19061	2,43,567	81,189	61226
Feb	28	2,93,328	3,360	8,400	3,05,088	80,000	12100	2,19,996	73,332	68234
Mar	31	3,24,756	3,720	9,300	3,37,776	70,000	8951	2,43,567	81,189	52976
Apr	30	3,14,280	3,600	9,000	3,26,880	70,000	9448	2,35,710	78,570	41253
May	31	3,24,756	3,720	9,300	3,37,776	70,000	18398	2,43,567	81,189	35443
Jun	30	3,14,280	3,600	9,000	3,26,880	-	61659	2,35,710	78,570	5932
Jul	31	3,24,756	3,720	9,300	3,37,776	-	325865	2,43,567	81,189	237587
Total					**39,77,040**	**2,90,000**	**10,56,82**	28,67,805		
Deduction of non working days (20 Days)					**37,67,520**	**2,90,000**	**10,56,82**	27,10,665		

Table 6.3.2 : Monthly water consumption and water sources

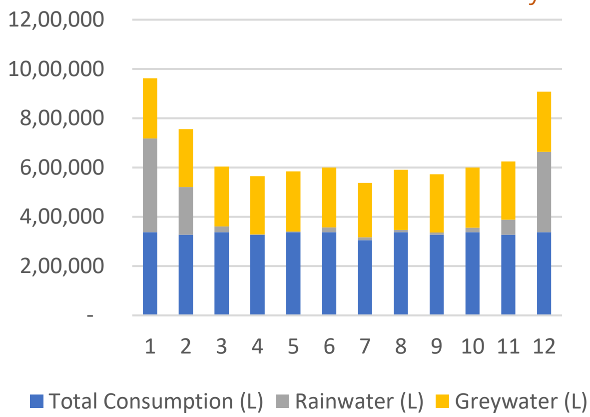


Figure 6.3.2: Water balance

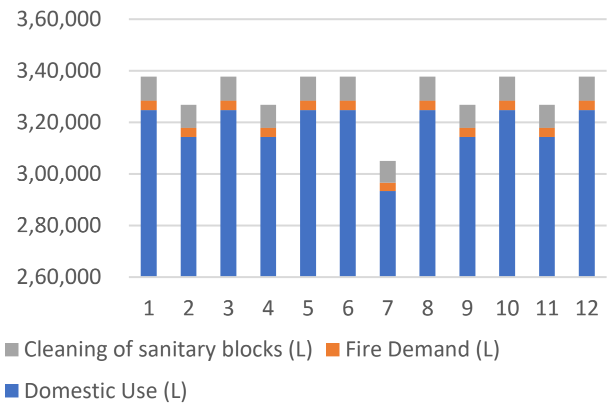


Figure 6.3.3: Water consumption

Total capacity of rainwater storage tank = 400 m3
Consider capacity of critical tank to be 5% of total capacity.
Hence, capacity of critical storage tank = 20 m3
For critical tank, consider h = 3m and l=b.
Hence, l=b= √20/3 = 2.5
Therefore, the size of critical storage tank will be 2.5m x 2.5m x 3m.

Now, capacity of main tank = 4,00,000 liters -20,000 liters = 3,80,000 liters = 380 m3
Here, we consider 2 tanks of same size. So, the capacity of each tank will be 380/3= 126.6 m3
Now, considering h = 3m, and l=b,
we get l = b = √126.6/3= 6.49m
Therefore, the size of each tank is 6.49m x 6.49m x 3m.

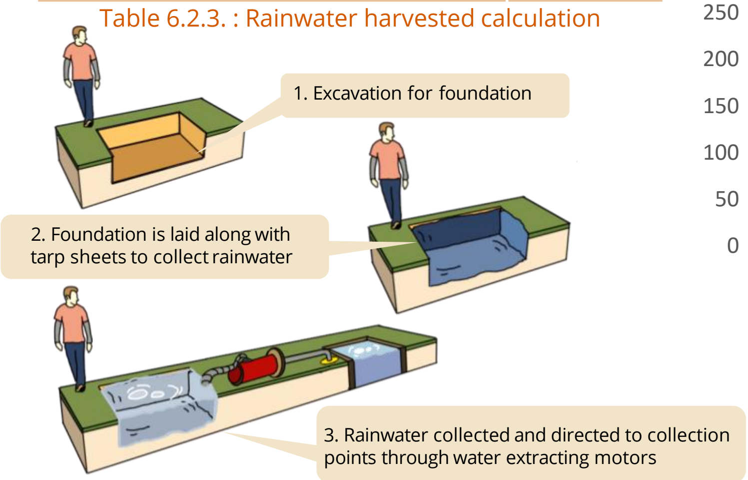
Jalsevak grey water recycling system- 1500 litre capacity
Treated greywater tank calculations:
Grey water generated in 1 days = 9000 liters = 9 m3
Now, considering h = 3m, and l=b,
we get l = b = √9/3 = 1.7 m
Therefore, the size of one tank is 1.7m x 1.7m x 3m.
6 tanks will be required.

6.2.3 Rainwater harvesting through rooftops and pits

The rainwater harvesting system incorporates rooftop harvesting, harvesting through stormwater and collection pits used by excavation. The integrated usage of these systems meets 28.05% (10,56,822L) of the annual water demand in this project. The systems include usage of pop-up filters to filter rainwater and vardan water filter for filtration needed for drinking water.

Supply Estimation	Catchment 1 (through roofs)	Catchment 2 (through site)	Catchment 3 (through canteen + kitchen)
Catchment area (m²)	1,150	4142.5	120
Runoff coefficient	0.7	0.2	0.2
Effective catchment area (m²)	805	828.5	24
Total effective catchment area (m²)			1657.5
Total average Annual rainfall (mm)			58
Total Rainwater harvestable annually (L)			10,568,22

Table 6.2.3. : Rainwater harvested calculation



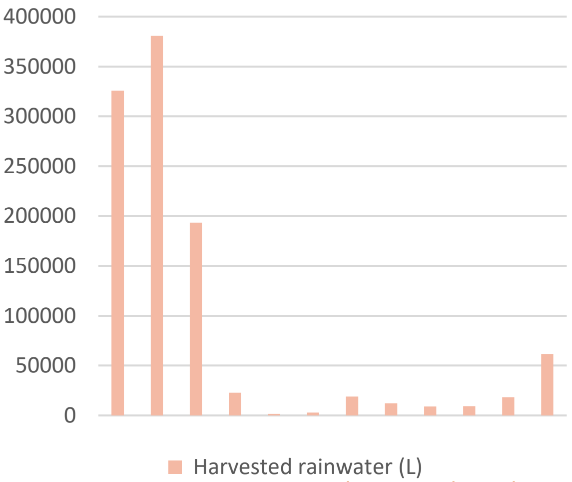


Figure 6.2.4: Rainwater harvested yearly

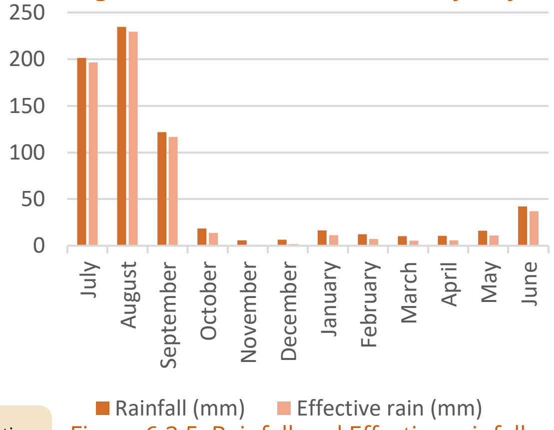


Figure 6.2.5: Rainfall and Effective rainfall

6.2.4 Water Performance: Pop Up Filter for RWH

The pop-up filter has three components: rainwater receptor, flush valve and filter element. Water received in the receptor flows upwards against gravity through a filter element to filter most of the floating elements and allow water to stabilize in this filtration zone. Pop Up filter is of 110mm and can handle rainwater from a maximum 1000 sq. ft. of roof area with very fine filtration- up to 250 microns

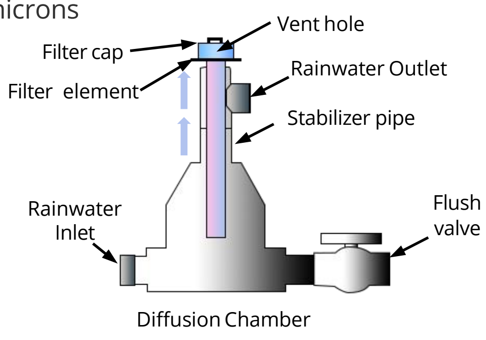


Figure 6.3.5: Diagram of Pop-Up Filter

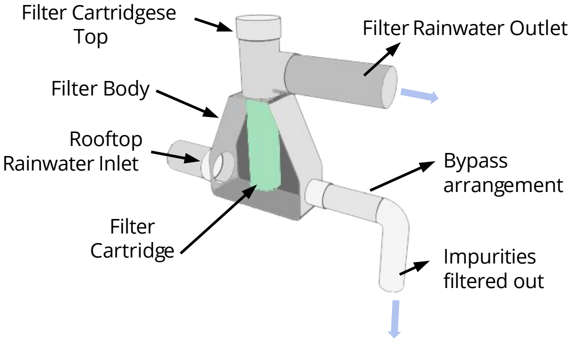


Figure 6.3.6: Working of Pop-Up Filter

6.2.5 Water Performance: Grey water recycling system

Greywater, which would otherwise be discharged outside, is collected and used to flush toilets. Sewage from all bathrooms and sinks is pumped into the recycling system. After recycling, greywater is pumped back into the toilet for flushing, into VAM and Radiant Cooling panels.

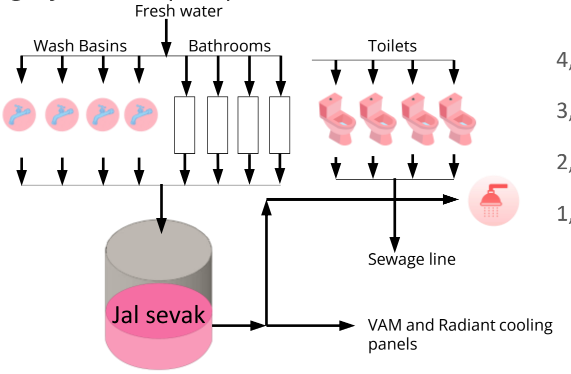


Figure 6.2.6: Greywater recycling system diagrammatic representation

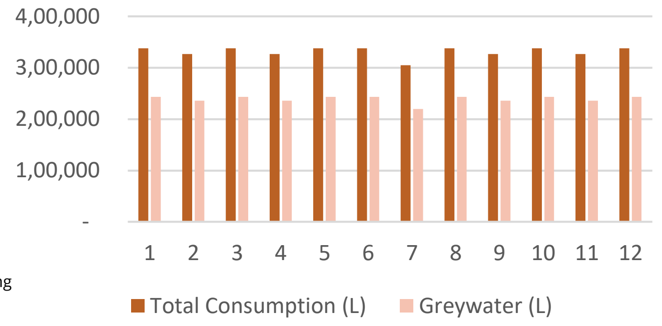


Figure 6.2.7: Consumption met through greywater

Annual water demand (liters)	**37,67,520**
Water demand met through rainwater harvesting	**10,56,822**
Water demand met through rainwater harvesting (%)	**28.05%**
Greywater recycling system (liters)	**27,10,665**
Greywater recycling system (%)	**71.95%**
Total demand met through sustainable systems	**37,67,487**
Percentage (%)	**100.00%**

Table 6.2.4: Water cycle diagram identifying uses and sources of waste along with reuse pathways

1. The WPI of a building is the ratio of the annual fresh water demand (L) per person per day.
2. Percentage reduction from GRIHA benchmark for WPI by **25%** from **120 L/person/day** to **90 L/person/day**
3. It is ensured that project meets water quality norms for drinking/domestic use as per BIS **10 500 : 2012** and treated water for discharge should be as per the **CPCB .**

6.2.6 Water Performance: Low-flow fixtures

Low flow fixture increase the water efficiency across all the units. Low flow fixtures used are-

 **D2D 3/6 liters Dual flush**	Two concentric buttons, pressing the circular button discharges 3 liters only and pressing both the buttons discharges 6 liters. Savings 4 - 7 liters/ flush(Standard flush uses 10-13 liters/flush)
 **Single lever mixer- Eco Disc Cartridge**	If the mixer tap is fitted with this type of cartridge, only the ecodisk devise must be activated turning it through 180° and the flow is reduced by 50 percent.
 **Flow regulators**	They limit the maximum flow from the tap in the washbasin, kitchen and shower as indicated, whatever the pressure of the installation and mix air. 8 litres/minute- 55 per cent
 **Water efficient showerheads**	Deliver water at 9 litres per second or less than that

6.2.7 Base case v/s proposed case water distribution

Spaces	Base case	Amount reduced	Proposed case
Bathing	55	27.5	27.5
Wash clothing	20	2	18
Drinking	5	0	5
Cooking	5	0	5
Washing utensils	10	5	5
cleaning	10	0	10
toilets	30	13.2	16.8
total	135	47.7	87.3
Percantage Reduction	**35.33%**		

Table 6.2.5: Base case and Proposed case water distribution

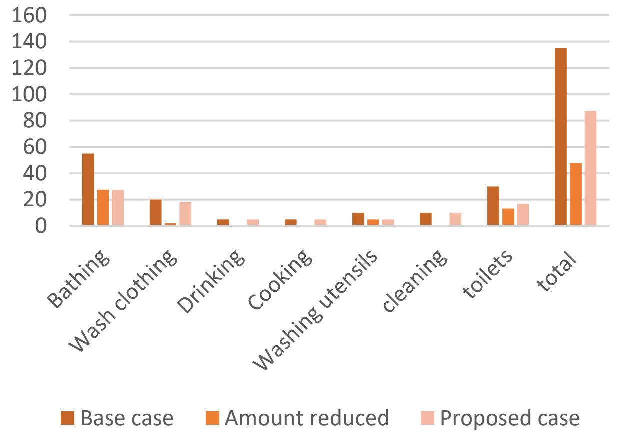


Figure 6.2.8: Base case and Proposed case water distribution

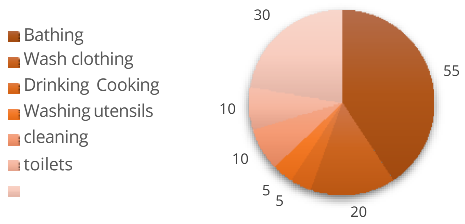


Figure 6.2.9: Base case water distribution

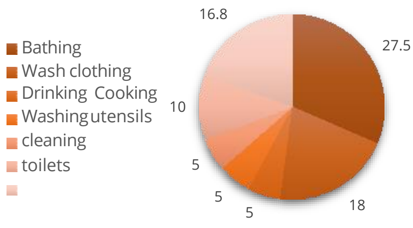
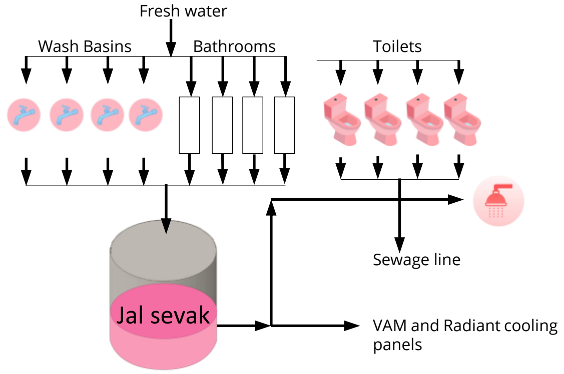
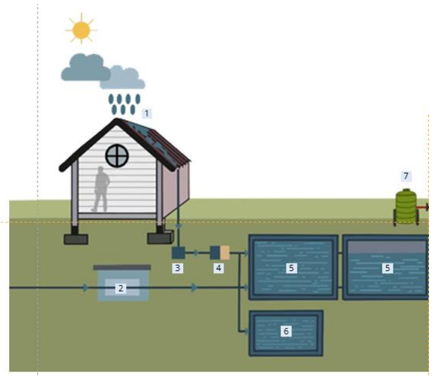


Figure 6.2.10: Proposed case water distribution

Water Performance: Rainwater Harvesting

The rainwater harvesting system incorporates rooftop harvesting, harvesting through stormwater and collection pits used by excavation. The integrated usage of these systems meets 22% (2,413,696 L) of the annual water demand in this project. The systems include usage of pop up filters to filter rainwater and Vardan water filter for filtration needed for drinking water.





6.4 Resilience

The site is located in Faridabad, Haryana and in accordance to the hazard map of India by the BMTPC, the site is prone to high damage risk zone due to earthquakes and where wind speed prevailing is 47m/s.
To bring the physical durability and resilience of structure the module is made of frp and grfg panels

6.4.1 Seismic vulnerability assessment structure

Various calculations show that the structures can be put together in single ,double or triple units and can with stand seismic load with out damage.
The module can be easily constructed and dismantled anywhere. The components of the module are easily transportable along with all its accessories. The constructed process is not very laborious and does not take a very long time to put together.

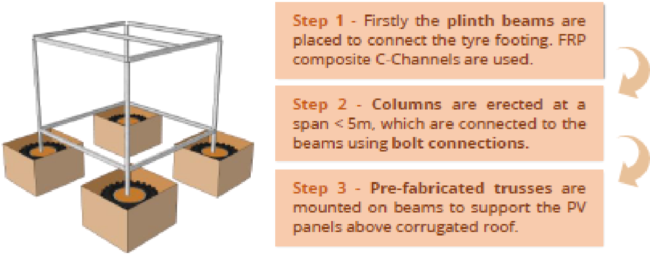
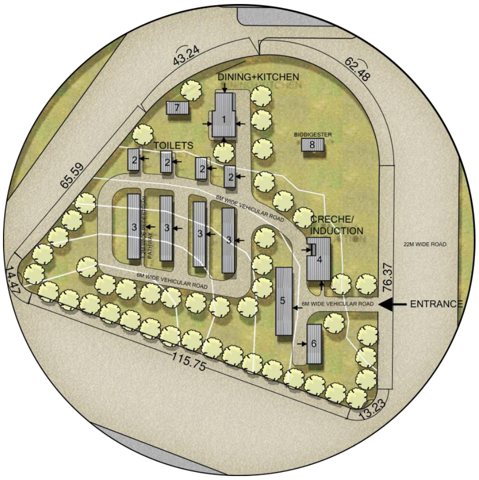


Figure 6.4.1: Process of assembly

1. Space

Preparedness and Functionality

The module can be easily constructed and dismantled anywhere. The components of the are easily transportable along with all its accessories.
The constructed process is not very laborious and does not take a very long time to put together.



2. Site

The site is aligned north-south, with the north providing less solar radiation and the south providing power generation from solar panels. The site plan has been developed using an informed design decision approach, with each simulation necessary for building block placement.

Energy Performance:

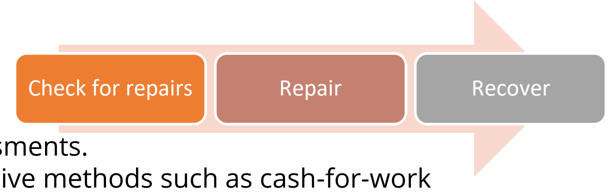
The site is enriched with renewable energy sources that provide electricity and hot water through solar PV cells, lowering reliance on fossil fuels and improving energy efficiency across the site.

Water Performance

On site level we are collecting water through Rainwater harvesting system which incorporates rooftop harvesting, harvesting through stormwater and collection pits used by excavation

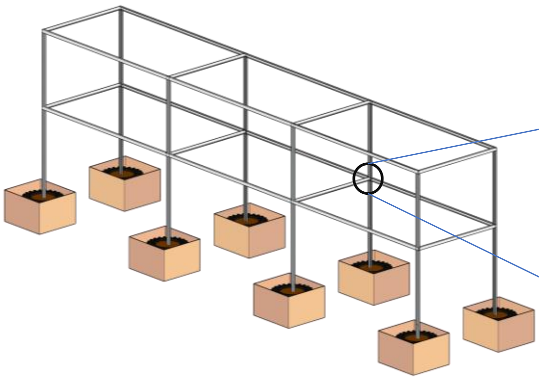
Recovery Plan –

In the case of emergencies the plan of action can be taken in three main phases –

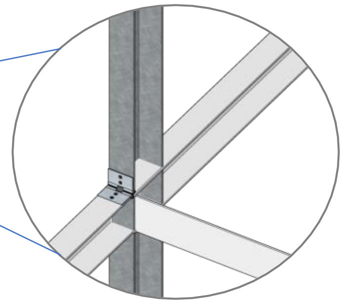


- Ensure that mass care and emergency services.
- Carry out the necessary damage and need assessments.
- Providing safe water supplies using labour-intensive methods such as cash-for-work
- Prioritize power supply restoration by repairing electrical facilities; local distribution substations are checked first, followed by main distribution supply lines.
- Debris and solid waste are reduced as obstacles and hazards, and primary transportation routes are cleaned up
- Clear farmland so that communities can replant their farms with the help of cash for work programmes
- Facilitate market access and market redevelopment.

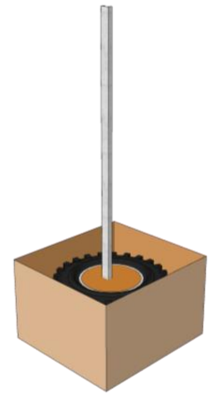
6.0 Design Documentation



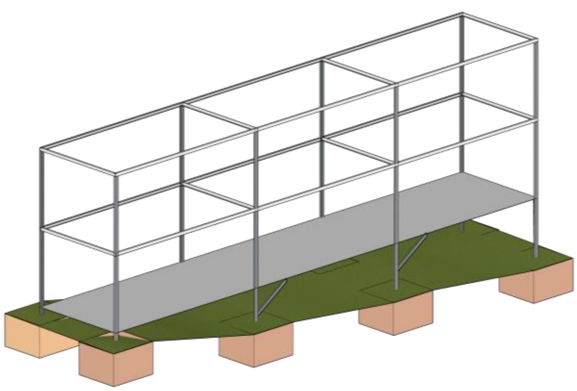
Framed Structure – FRP column, beams



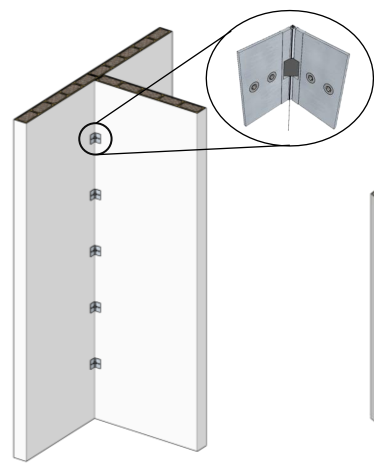
'L' – Plate Joinery



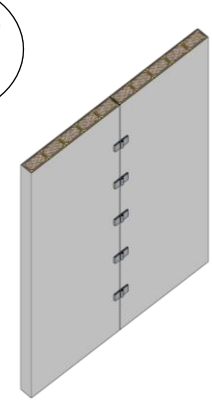
Tyre foundation 18 x 18 x 24"



Bracing for extra structural stability

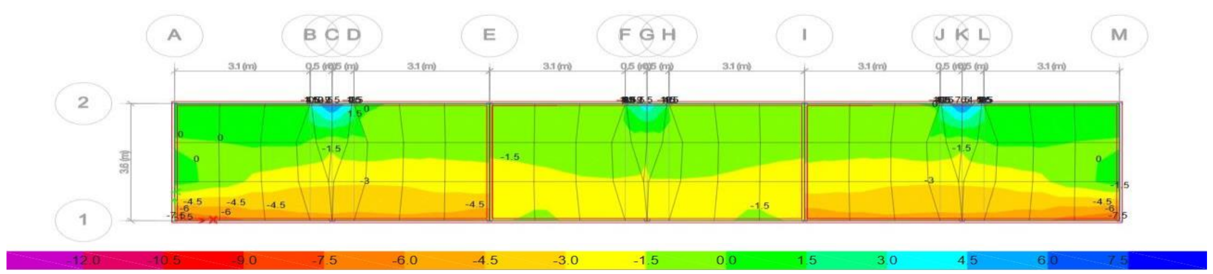


'L' – Panel Joinery



'I' – Panel Joinery connected with nuts and bolts

- Tyre Foundation can act as dampers in situations such as earthquakes and heavy wind flows
- GFRG panels are structural stable in such situations because of there self weight
- Steel joineries with nuts and bolts are used for stronger stability
- Bracing are used in contoured regions for extra support from the foundation level
- FRP beams and columns as they have good young's module of elasticity
- The deflection in the slab is not much and hence the slab is structurally stable.



6.5 Affordability

6.5.1 Capital cost

The initial cost investment i.e. capital cost of the whole project is reduced by renting out the materials and components.

S.No	Components	Life span	Single unit cost	Cost considering as rented material (per year)	Factor
1	GFRG wall panels	80	40000	2750	160
2	FRP skeletal frame	25	465	102	280
3	Tyre foundation (can't reuse)	10	1050	1050	70
4	Corrugated metal sheet	100	2850	157	64
5	GFRG panels flooring	80	40000	2750	40
6	Solar panels	20	20000	5500	46
7	Grey water reycling system	15	240000	88000	2
8	Septic tank	15	13600	4987	1
9	Windows	50	5000	550	80

Table 6.5.1: Example of the prices used for the cost calculation

The final cost of the components is calculated with the 10% profit margin for the retailer. All the components are rented for 3 years. The price is reduced by 87% by renting for 3 years the components instead of buying the components.

6.5.2 Component selection based on the location basis

The components used in the whole project are available in New Delhi which is within a radius of 50 Km. All the materials that are rented can be repaired using the online service providers. Tires were used in the foundation of the buildings in the project which are reusable tyres that reduce the cost by 90%

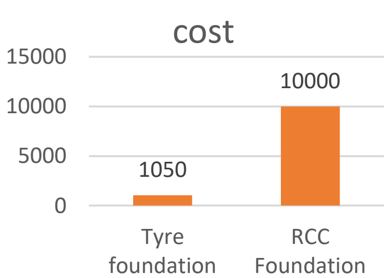


Figure 6.5.2: Cost comparison of foundations

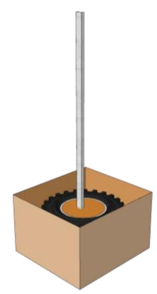


Figure 6.5.3 : Tyre Foundation

Figure 6.5.4 : Proximity of Faridabad

6.5.3 Strategies considered for Capex reduction

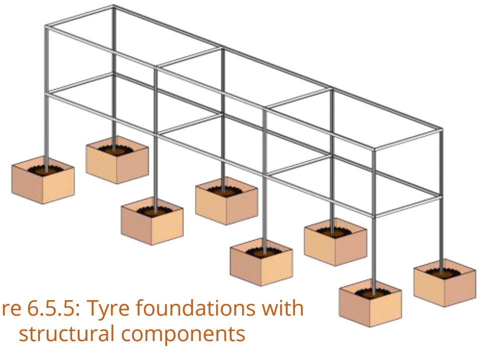


Figure 6.5.5: Tyre foundations with structural components

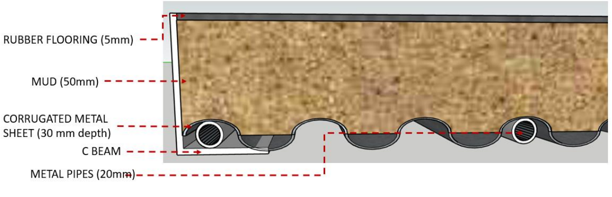


Figure 6.5.6 : Customized Radiant panels wilt mud-filled corrugated sheets.

Figure 6.5.7: Rainwater storage Tank

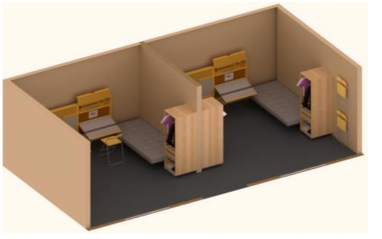


Figure 6.5.8: Wall-mounted Furnitures

6.5.5 Strategies considered for Opex reduction

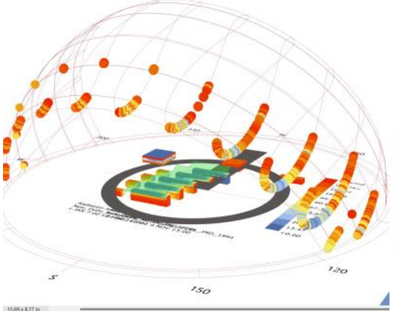


Figure 6.5.9 : Orientation

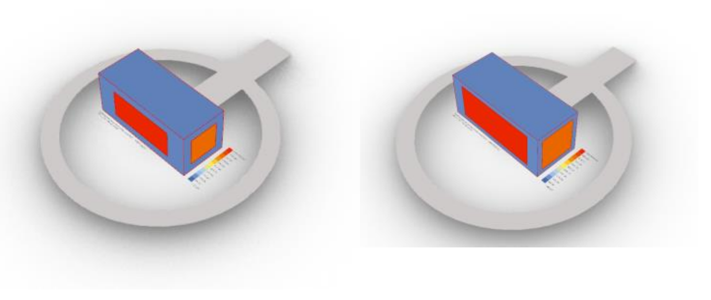


Figure 6.5.10 : Window to Wall Ratio

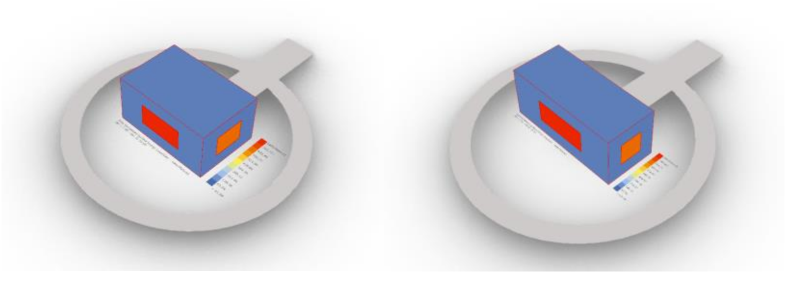


Figure 6.5.11 : Aspect Ratio

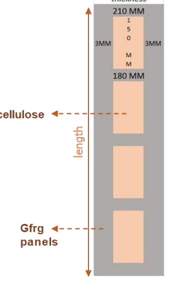


Figure 6.5.12: Thermal Transmittance of the Envelope

Figure 6.5.13: Vapour Absorption Machine (VAM)

The total operation Expenditure is optimized with the above-mentioned strategies (variables) which resulted in the Reduction of EPI and further resulted in the operational costs. Informed design decisions helped us to cut down the costs in multiple ways by directing the decisions in the pre-design analysis of the whole project. Using the rented components makes it have very few maintenances of the components for the whole project time which is about 3 years as they are repaired before the installation.

6.6 Innovation

6.6.1 Identification of problems in Delhi

- **Waste:** Delhi produces 141000 tonnes of waste per day
- **Water shortage:** In what comes as a potential worry for citizens of the national capital, water supply will remain affected today (that is, Sunday, November 7) across several parts of Delhi due to an increase in ammonia pollution in the Yamuna river impacting operations at treatment plants.
- **Ac cost high:** The Delhi government is considering increase in tax on air-conditioners, which are selling like hot-cakes with mercury sky-rocketing.
- **Integration**- Our innovation not only saves water and regenerates energy from waste but also helps us in reusing it in an efficient and non-invasive way.

Potential For Fast Scaling Up

Cost of a conventional ac system and Water treatment plant is **2.5 Lakhs.** On the other hand , individual ac units and water treatment plants are way larger than our system and in terms of cost of transportation and sourcing, it is very inconvenient to use these large units.

Once out in the market our innovation will have the market potential to do well as it not only reuses the water, but it also helps in providing thermal comfort in summer and winter.

Potential For Reduced Environmental Impact

It is found that Indians are more likely to buy 300 MN ACS in 20 years and they're choosing brands & features over energy efficiency**.**

New Delhi: Those buying air conditioners (ACs) in Delhi-National Capital Region (NCR) made their choice on the basis of the brand, features and price points, and energy efficiency considerations weighed less on their choices, a study that mapped patterns and preferences of more than 2,000 households between July and September 2019 has found.

Emphasising that factors like higher price and low availability of energy-efficient ACs prevented people from buying them, the study highlights the opportunity for decision-makers and businesses to incentivise purchase of more energy-efficient appliances. In the next 20 years, the government expects that 300 million room ACs will be purchased in India. This has implications for India's greenhouse gas emissions and for its clean-energy plans. However not all individuals want to focus on branded and efficiency. Cost plays a major role and as a result, majority of these air conditioners emit high amounts of co2 and are hazardous to our environment. VAM works on waste heat or solar energy, we are actually conserving energy instead of generating it and no toxic gas is emitted. Thereby, this is a very fruitful solution to combat future issues related to climate change and also provide a cost effective and portable solution which has the potential of gaining popularity in the future.

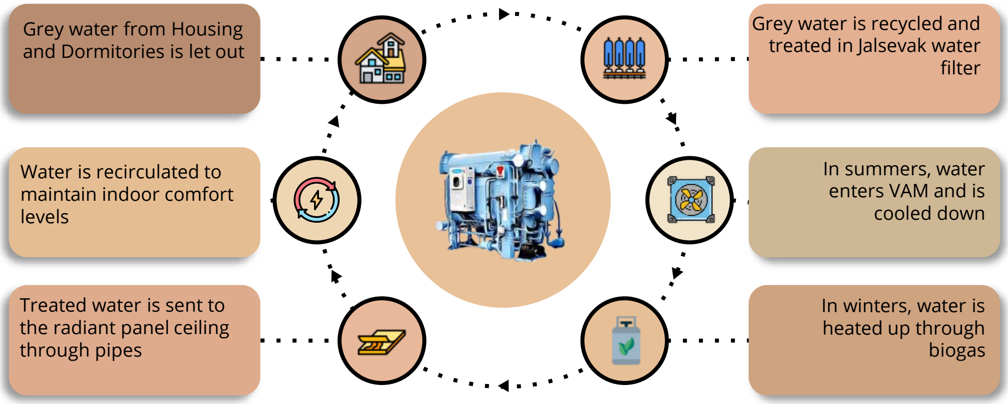


Figure 6.6.1 : Diagrammatic representation of VAM

6.5.2 Vam Process And Waste Generation

Parameter	Calculation
Total human waste generated	7.4 grams / day / person (100 people = 74 kg /day
1.95 cubic meter gas feeds 8 people 2-3 meals a day	
Biogas produced	1.95 x 0.657(density)=1.28 Kg/ day
Heat produced	436.8x 1.28= **559 KJ**
Bio digestion time 2-3 days maximum increased concentration time	

Table 6.5.1: Waste Generated

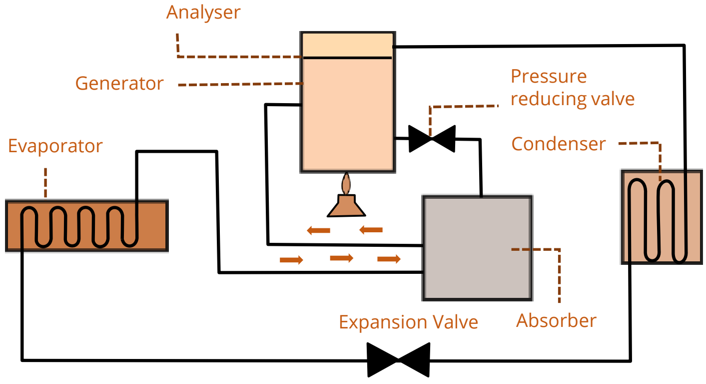


Figure 6.5.2 : Diagrammatic representation of vapor absorption machine (VAM)

6.6.3 Radiant Panels in Delhi

- Water chilled from the VAM will be passed through the radiant panels fixed on the roof and thus exchange of heat will take place and cause a cooling effect in the rooms
- Water cooling system saves 6 times more power than air cooling system and hence helps in saving energy
- Radiant cooling panels are generally attached to ceilings,
- Controls in the panels can more quickly adjust to changes in outdoor temperature.

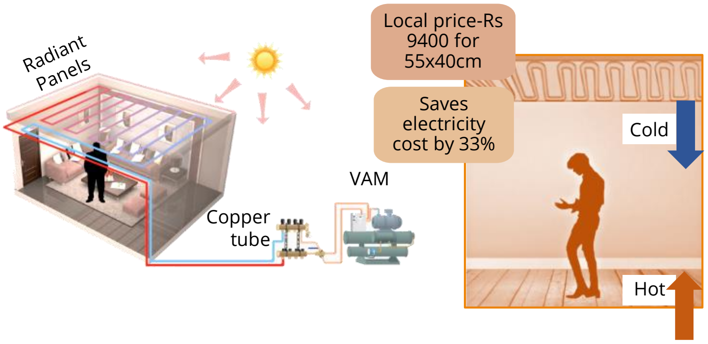


Figure 6.5.3 : Diagrammatic representation of Radiant cooling panels

- Since the temperature in Delhi is higher in the summer months which leads to power consumption of cooling devices, radiant panels in addition to lowering down the cooling load also help in reduce the electricity bill.

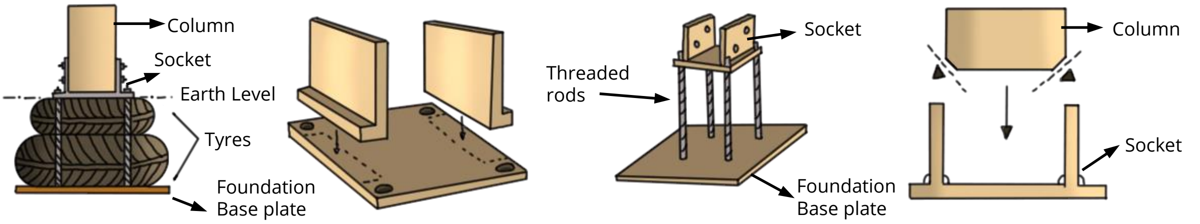
6.6.4 Tyre Foundation

Tyre foundations are low-tech solutions consisting of scrap rubber and compressed gravel. These materials are readily available almost everywhere in India. It is a low-tech solution which is composed only of scrap tyres filled with compressed gravel. Both components are easily accessible almost everywhere in the world.

Indeed, when tyres worn out, they become a waste which is not easy to handle. Recently, more processes that aim at recycling have been developed from which rubber, steel and textile fibers are obtained.

Delhi is prone to seismic activities from its neighboring states, Hence These foundations can reduce the effect of seismic vibrations on the building. Furthermore, it can be used in every stable soil.

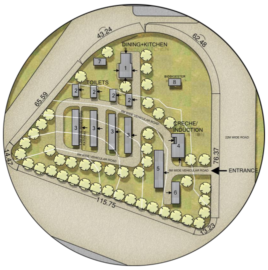
A tyre foundation in its simplest form is only made from dirt and scrap tyres and is therefore free. This method is suited for retaining walls and foundations that don’t require anchoring which is perfect for our project typology.



10.6. Health and Well-being

10.6.1 Site strategy

The residential blocks are positioned on the upper contours and orientated towards the windward side, with alternate ground and stilt levels.



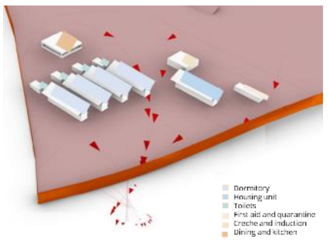


Figure 10.6.1: Planning wind flow in site

10.6.2 Hygiene

Toilets are hygienic, reducing pollution and promoting a healthy environment by keeping rainwater from entering. The indoor environmental quality conditions is maintained for nearly 86.2% of occupied hours in the year. Bio clean biodigesters have been installed at the site and have the capacity to anaerobically decompose a variety of organic compounds/faucal sludge in the biodigester tanks. This aids in the avoidance of pipeline and drain blockages, as well as the total elimination of unpleasant odors.

10.6.3 Ventilation in rooms

A partition placed parallel to the incident wind has little influence on the pattern of the air flow, but when located perpendicular to the main flow. Provision of a partition with spacing of 0.3 m underneath helps augmenting air motion near floor level in the leeward compartment of wide span buildings.

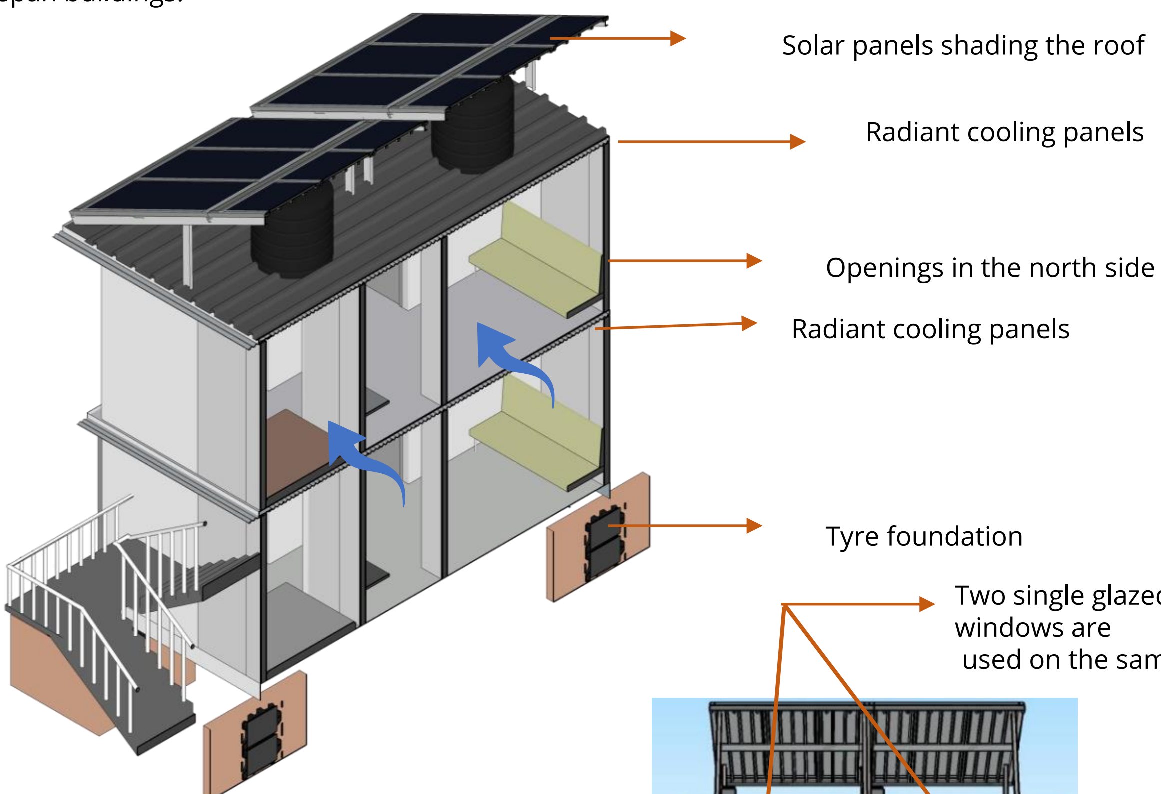


Figure 10.6.2: Facilitating air movement indoor

In the case of rooms with only one wall exposed to outside, provision of two windows on that wall is preferred to that of a single window.

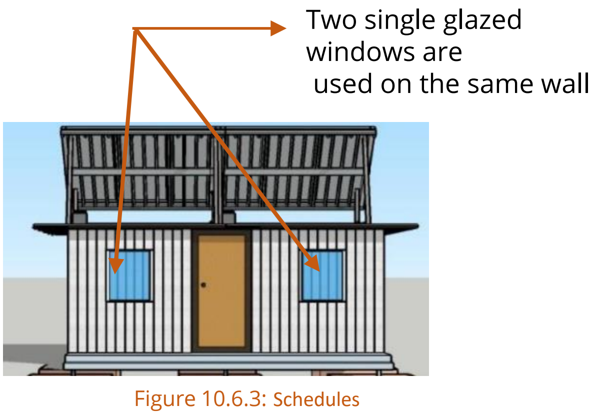


Figure 10.6.3: Schedules

6.6.4 Thermal Comfort

Space type	No. of occupant	Rp (l/s.person)	Floor Area (m2)	Ra (l/s.m2)	Ventilation rate (l/s)
Dormitories	4	2.5	29.52	0.3	18.86
Housing	4	2.5	29.52	0.3	18.86
Kitchen	4	3.8	20.00	0.6	27.20
First Aid	4	8	29.52	0	32.00
Quarantine	4	13	29.52	0	52.00
Creche	7	5	43.66	0.9	74.29
Induction Room	30	3.8	52.44	0.3	129.73

Table 10.6.2: Ventilation rate

Options	Room H	Room L	Room D	Room volume	ACH	Flow Rate	Opening Height	In Temp	Out Temp	Discharge Coeff	Area of Opening
	H	L	D	V	ACH	q	h	Ti	To	Cd	A
1	3	7.2	3.6	77.76	3	0.065	1.1	34	35	0.25	1.38
2	3	7.2	3.6	77.76	4	0.086	1.2	34	35	0.25	1.76
2	3	7.2	3.6	77.76	4	0.086	1.3	34	35	0.25	1.70

Table 10.6.2: Natural ventilation openings

6.6.5 Passive strategies for thermal comfort

Placement of blocks

All the blocks have openings from the north direction so that we have cool light entering the space throughout the day and solar panels are directed towards the south direction for maximum solar heat gain.

Create social value

The first floor the stilt floor shade the south façade creating sun social spaces for interaction of people.

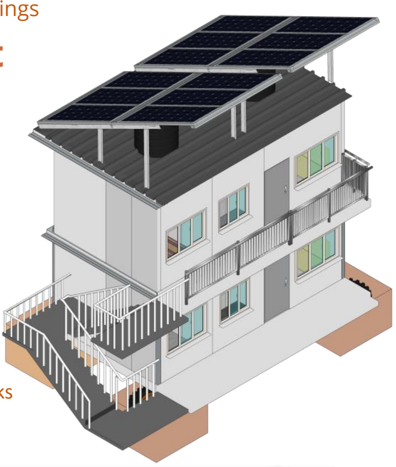
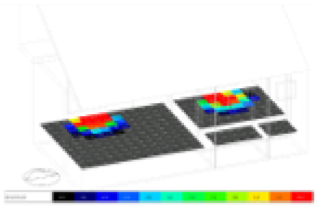
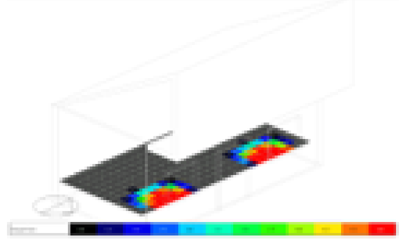


Figure 10.6.5 Position of blocks

6.6.6 Daylight factor





The maximum operative temperature is 32 °C which is at the unoccupied hours only, which is 03:00 pm. The Daylighting result in figure 2 and 4 for dormitory and housing block at most extreme day of the year has been simulated for which the daylight factor fall in a range which Is sufficient for the daylight to be admitted into the space for proper visual comfort.

6.8 Engineering and Operations

6.8.1 Load Distribution pattern and Seismic vulnerability assessment

The Load distribution patter has been calculated and analyzed for all the blocks along with Seismic
vulnerability assessment. The following analysis helps us understand the load pattern or transfer from the superstructure to the substructure, how stable the material is structurally and under the influence of seismic load, apart from the traditionally used materials. The beams and columns are Fibre reinforced channels which are joint with nuts and bolts to the (GFRG) Glass Fibre Reinforced Gypsum Panel.

The following is the structural analysis for a single unit, understanding how the load is transferred and how the unit is structurally stable.

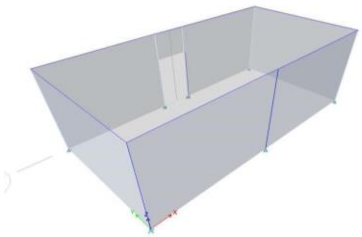


Figure 6.8.1: Single unit block model

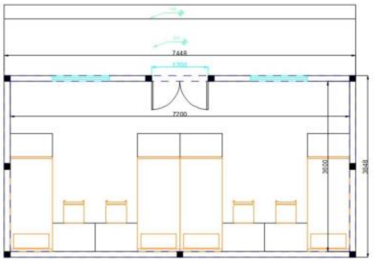


Figure 6.8.2: Single unit block plan

Load Distribution of roof:
In figure 6.8.3 , we can see the load distribution of the roof where the deflection is negligible and the load from the roof can be taken by the columns and beams.

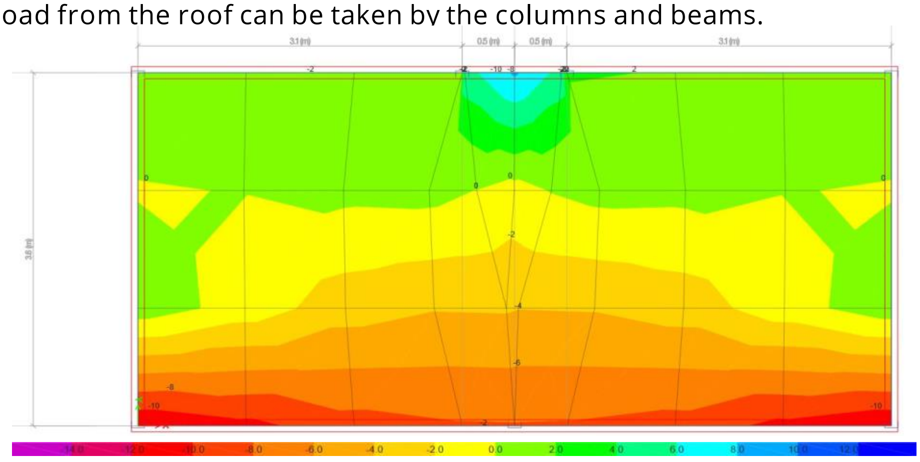


Figure 6.8.3: Single unit block with load distribution on roof

6.8.2 Structural analysis : Shear Force Diagram and Bending Moment Diagram

<u>Seismic vulnerability assessment</u>
This calculation presents the automatically generated lateral seismic loads for load pattern seismic according to IS 1893:2016, as calculated by ETABS. See figure 10.2.7.
Seismic Zone Factor, Z [IS Table 3],Z =0.24
Response Reduction Factor, R [IS Table9] R =5
Importance Factor, I [IS Table 8],I =1 Site Type [IS Table 1] = II

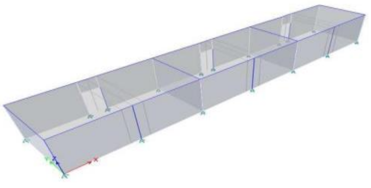


Figure 6.8.4: Three unit block model

Since it's a single story and the lateral load to stories is 10.72kN. The single unit is safe from seismic load and is represented in figure 10.2.2 Figure 10.2.8 shows the structural analysis for a three unit stacked together for Dormitory and Housing, understanding how the load is transferred and how the unit is structurally stable.

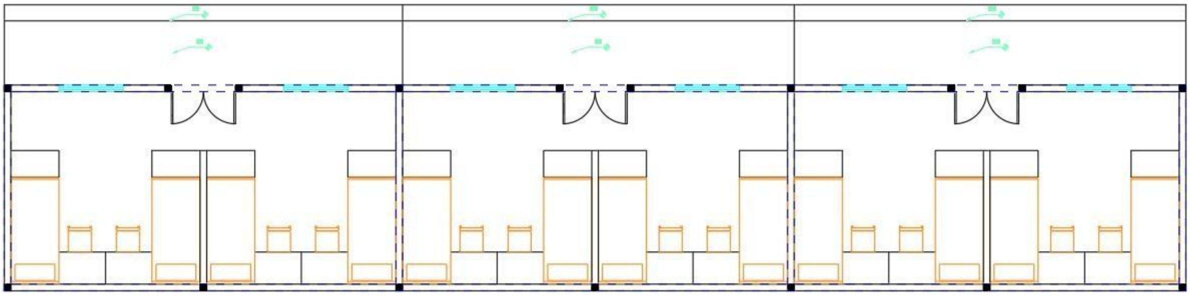


Figure 6.8.5: Three unit block plan

In figure 10.2.10, we can see the load distribution of the roof where the deflection is negligible and the load from the roof can be taken by the columns and beams.

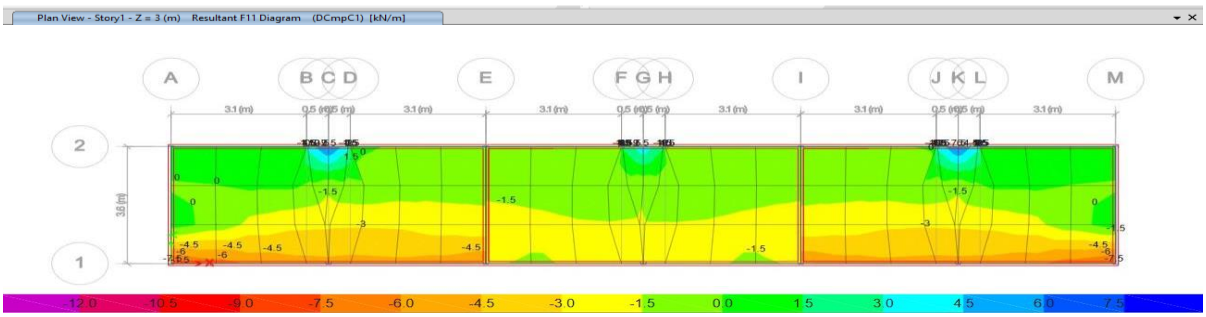


Figure 6.8.6: Three unit block plan with load distribution on roof

6.8.2 Shear force diagram and bending moment diagram

<u>Seismic vulnerability assessment</u>

This calculation presents the automatically generated lateral seismic loads for load pattern seismic according to IS 1893:2016, as calculated by ETABS. See figure 10.2.11.

Seismic Zone Factor, Z [IS Table 3] Z =0.24
Response Reduction Factor, R [IS Table9] R =5
Importance Factor, I [IS Table 8] I =1

Site Type [IS Table 1] = II
Since it's a triple story and the lateral load to stories is 31.004 kN.
The triple unit stacked together is safe from seismic load and is represented in figure 10.2.3.

6.8.3 Assembly and Disassembly of structure

Modular nature

The module can be easily constructed and dismantled anywhere. The components of the are easily transportable along with all its accessories. The constructed process is not very laborious and does not take a very long time to put together.

Diagrammatic representation of assembly and Disassembly

Process of Assembly

Step 1 – The tyre foundation bolted to the **FRP columns** and the **steel floor joist ,** through bolt connections the **corrugated sheet** is connected to **floor joist** on top of which the **rubber flooring is laid.**

Step 2 - Columns are erected at a span < 5m, which are connected to the beams using **bolt connections**.

Step 3 – The steel joist and **FRP Composite C channels** are connected using bolt connections to support the **corrugated sheets and steel pipes** used for **cooling and heating. Mud** will be laid on top of the corrugated sheets for **insulation** and covered with **rubber flooring.**

Step 4 - Pre-fabricated trusses are mounted on beams to support the PV panels above corrugated roof.

Process of Disassembly

Step 1 – Remove the **PV Panels** above the **corrugated sheets** and the **pre-fabricated trusses** after which remove the rubber flooring and the top layer of **mud** followed by **corrugated sheets.**

Step 2 – Remove the **steel pipes** and unbolt the **steel joist and FRP composite C channels.**

Step 3 – unbolt the beams and columns.

Step 4 - Rubber flooring and mud has to be removed. **The column** and **floor joist** are unbolted from the **tyre foundation.**

6.8.4 Material

The design adopts GFRG panels (glass fiber reinforced gypsum panels) as wall material with a thickness of 122mm and cellulose (9mm) as insulation material.
Corrugated Steel Sheets (7 mm thickness) are utilized for roofing. corrugated metal roofs will resist adverse weather conditions more than many other materials.

The panels are manufactured at factories and brought at the site directly and fixed on the structure like a Lego system. Once a foundation is laid, these panels are erected on the foundation with the help of cranes.

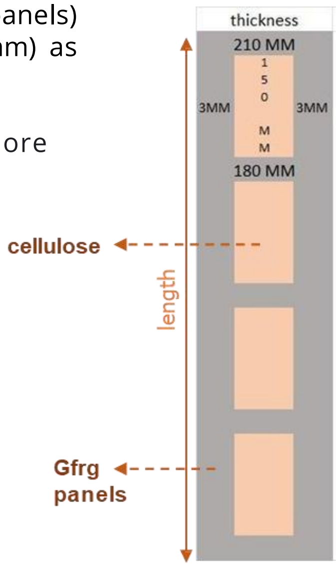
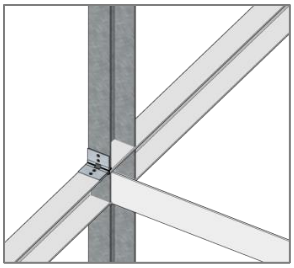
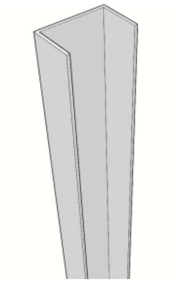


Figure 6.8.7: Wall Section

Material Used:
1. Steel floor joist
2. FRP C channels
3. Steel Corrugated sheets
4. Steel pipes
5. Mud from site excavation
6. Rubber flooring
7. GRP

10.7.7 Joinery details + connections +structural design





10.7.8 Tyre foundation

Tyre foundations are low-tech solutions consisting of scrap rubber and compressed gravel. These materials are readily available almost everywhere in India. Additionally, the flexibility of the tyre can provide durable protection from seismic activity. Foundations like these can indeed reduce seismic vibrations on structures erected on top of them, and they can be erected on any stable soil.

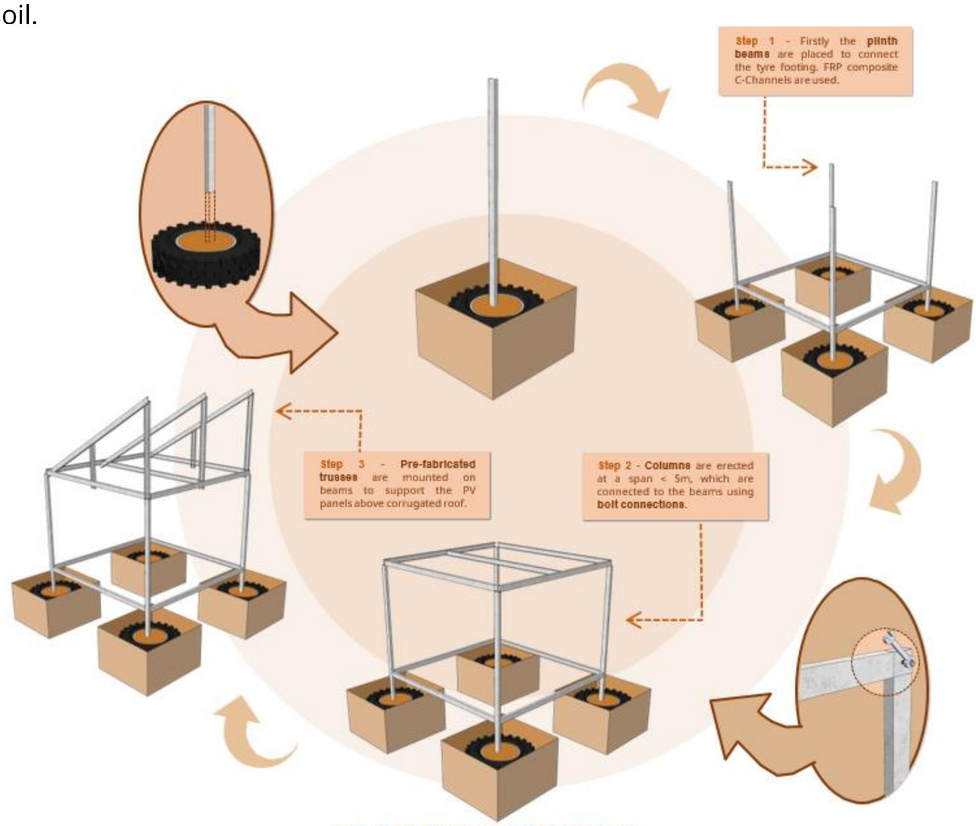


Figure 10.7.9 Process of Assembly

10.7.9 HVAC Radiant Panels

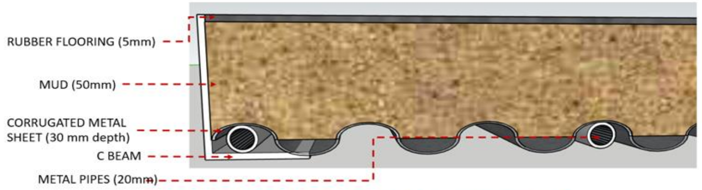


Figure 10.7.9: Cross section of the radiant panel roof

Figure 10.7.9 is the cross-section view of the radiant panels that will provide cooling and heating to the space in the mixed-mode condition. There is corrugated sheet of 7mm thickness, in the depression of the corrugated sheet 20 mm metal pipes are provided through which cooling or heating water passing will help maintain the indoor thermal comfort. The water which is passing through the pipe is cooled due to the vapor absorption machine. Next layer is 50 mm mud layer which is mixed with cow dung to improve the cohesion within the soil and water particles. This will help hold the moisture and keep the mud intact. The topmost layer is the Rubber flooring of 5mm thickness.

6.9.1 Scalability

The module that we designed are the panels. The usage of the panels gives the liberty of design according to the site all over the country.

Details of the panels with the dimensions are to be discussed with the construction process under this section. Wall-mounted single beds and table are used.

Figure 6.9.1: Typical living module

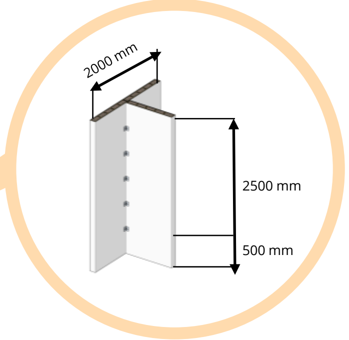


Figure 6.9.1:Panel Dimensions

6.9.2 Market Potential

According to NSSO, there are a total of 74 million of construction workers in urban areas. 35.4% workers of the total workers are migrants. That makes it a total of 24.78 million migrant onsite construction workers in the urban areas[1].

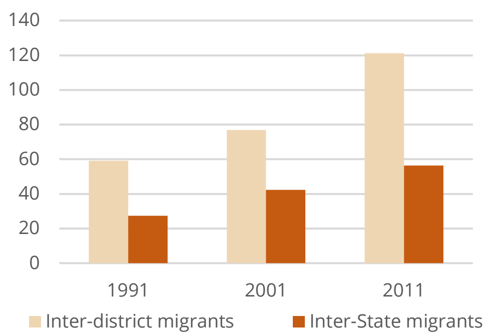


Figure 9.2.1: Inter-district vs inter state migrants in India

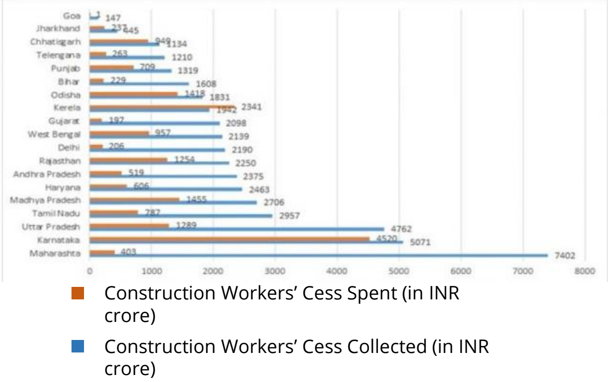


Figure 9.2.2: Construction Workers Cess

There are a total of 5 gfrg companies are spread over the country. A total of 775 districts in India which has packers and movers logistics companies which can transport the panels. The panels dimensions are chosen on the parameters of ease of transportation and ease of mantling and dismantling for the construction. The repairs of the construction components after the transportation of them to the other site can be done by the home service providers companies like house joy and urban clap which covers around a total of 47 cities in India. All the building components used can be rented instead of buying it which reduces the capital expenditure on the components as it is temporary construction which will be used for a maximum of 4 years. Most of the components/ materials used in the modules are reusable.

Figure 9.2.3: GFRG Companies across India

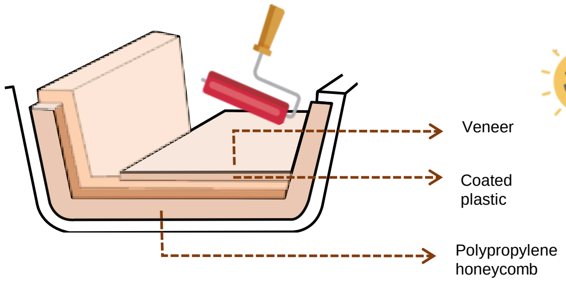


Figure 9.2.4: Typical Polypropylene honeycomb panel

Why are we adopting **polypropylene honeycomb** in the production of furniture?

Polypropylene honeycomb's finish makes it easy to bond with other miscellaneous materials, so a wide choice of facing materials is available when this material is used.

Advantages of the sandwiched material

Strength and durability

It lightens the furniture's overall weight without sacrificing its strength or longevity.

Ease of transportation

As these are lighter than solid material panels, they are easier to pack and transport.

Lightweight

Because it is lightweight, it can be utilized for wall-mounted furniture.

Relation to contests

Scalability and market potential
The scale of the furniture is exactly up to the requirements of the housing unit. Any extra furniture/ item has not been wasted.

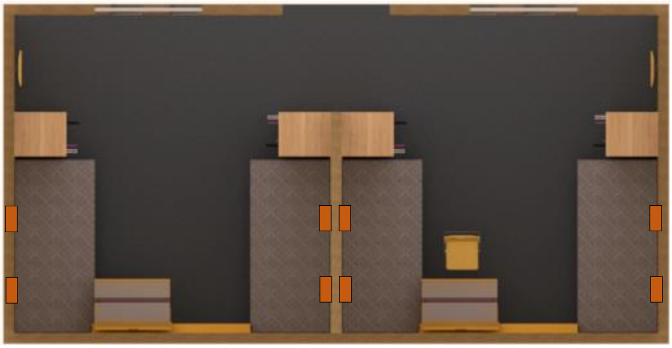


Figure 9.2.5: Wall mounted nature of furniture used

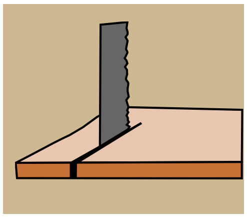
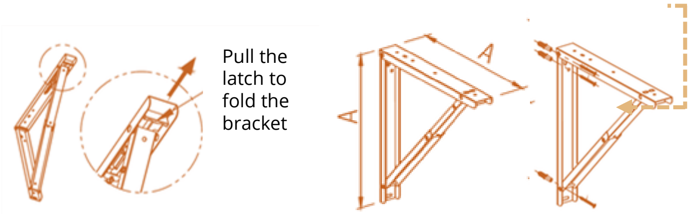
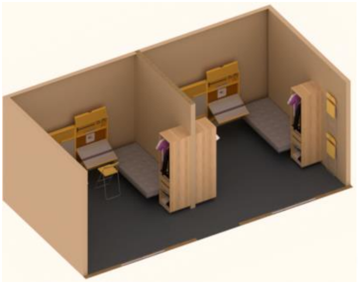
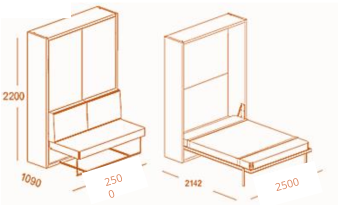


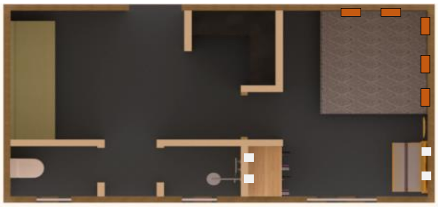
Figure 9.2.6: Foldable/ lightweight nature of furniture used

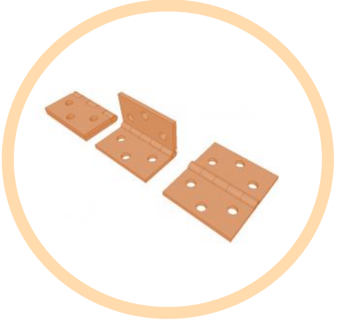


- ✓ Niches will be carved on the walls for the folding furniture
- ✓ Hinges will be used as connecting elements
- ✓ Foldable bracket will be used as structural member to transfer the load onto the wall









Wall mounted WC and water faucets are used

Sofa can be converted into a bed to accommodate more people in living room

Furnitures used in family unit
- ✓ Study desk
- ✓ Kitchen slab
- ✓ Chairs
- ✓ Hinged bed
- ✓ Storage unit
- ✓ Sofa cum bed

Hinges used for connecting elements

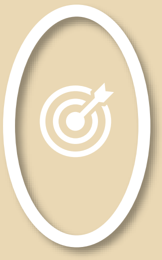
6.0 Design Documentation

6.10 Communication

Integration of Communication within Team Samanvit

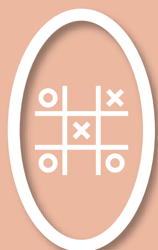
Communication as a contest has been of utmost importance to Team Samanvit through out the timeline of the Solar decathlon competition, India. As a team, our members always shared core values including sustainability and towards net zero, but also believed in inclusion and coming together as a greater one, thus coming up with the name “Samavit”.

Our Goals and strategies towards Communication as a contest



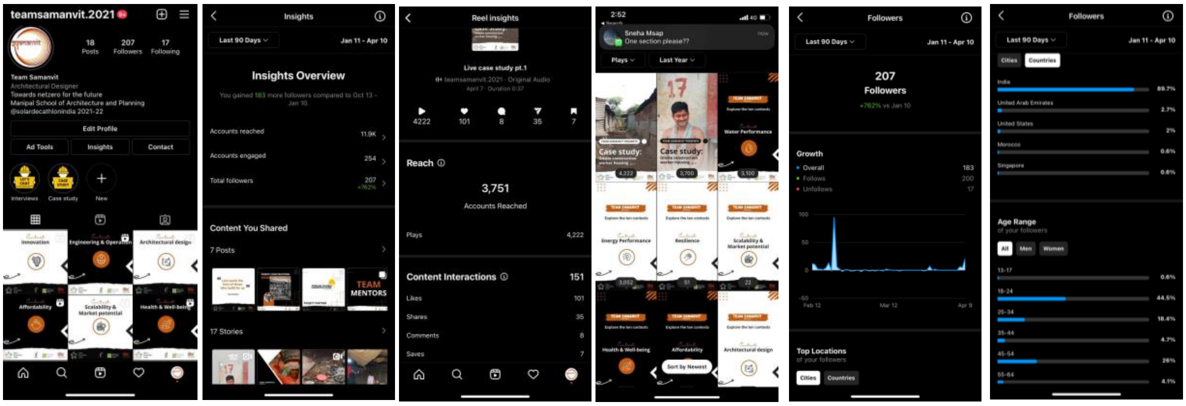
Goal

- ✓ To tap into a audience that is aware of ongoing conditions and is able to bring about change
- ✓ Bring about awareness to different age groups – professionals and youth of the future
- ✓ Market a product that emphasizes the need of the hour and the potential of the product to bring about good changes to the present state of things



Strategy

- ✓ By marketing on platforms with current professionals around the world like LinkedIn
- ✓ By marketing on popular platforms used by the youth of the future like Instagram
- ✓ By posting a sequential order of events for clear awareness of the onsite construction workers and a simple solution



Our Account: teamsamanvit.2021

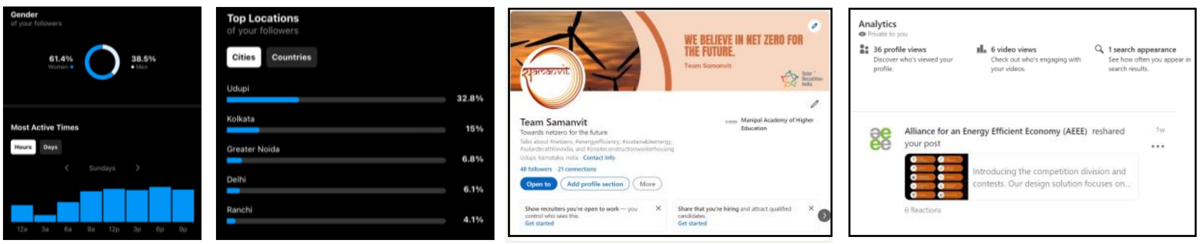
Total posts: 18 Accounts reached: 11.9K
Followers: 207 Accounts engaged: 254

Most popular post: Case study pt.1

Accounts Reach: 3,751 Likes: 101
Plays: 4,222 Shares: 35

Overall Insights from Last 90 days

Growth: 183 Age group: 18-24
Percentage: +762% Country: India

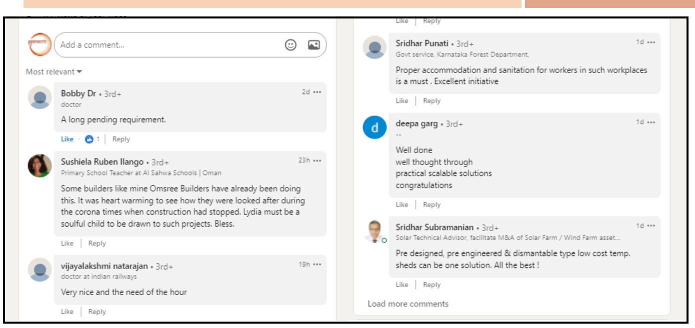


More insights

Reached 61.4% Women and 38.5% Men
Most Active hours: 12 pm - 6 pm

Our LinkedIn Account: Team Samanvit

36 profile views 6 video views 1 search appearance



More details

Instagram account:
https://www.instagram.com/teamsamanvit.2021/
LinkedIn account:
https://www.linkedin.com/in/team-samanvit-17513a234/

Engagement rate: 0.0069 Total comments: 8
Reshares: 35 Likes: 101
Publication:18 Shares: 35

Official contact email: teamsamanvit.2021@gmail.com

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