Solar™ Decathlon India

TEAM econique

DIVISION

ON-SITE CONSTRUCTION WORKER HOUSING

DELIEVERABLE 04

FINAL DESIGN REPORT

APRIL 2023

मौलाना आज़ाद
राष्ट्रीय प्रौद्योगिकी संस्थान भोपाल (म. प्र.) भारत
MAULANA AZAD
NATIONAL INSTITUTE OF TECHNOLOGY BHOPAL (M.P.) INDIA

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REVIEW RESPONSE

REVIEW 1

S.NO.	SECTION	REVIEWER'S COMMENT	OUR RESPONSE
1.	Energy Performance	Further elaboration of calculations.	Detailed calculations are provided on page
		Comparison and analysis of the baseline and proposed design.	Revised work is provided on page
2.	Water Performance	Fixture details to be provided alongside the comparison and analysis of baseline and proposed design.	Recommended details are provided on page
3.	Embodied Carbon	Provide Visual on the construction material and technology.	Mentioned details are provided on page
4.	Resilient Design	Add more quantitative assessments.	Additions are made as per the review on page
5.	Engineering and Operations	Great work.	---
6.	Architectural Design	Great Detail.	---
7.	Affordability	Excel sheet have some few data missing. Add cost estimation table along with excel.	Rectified the excel sheet and added cost estimation table on page
8.	Innovation	Good attempt.	---
9.	Health and well being	Good work.	---

TABLE A : REVIEW 1 RESPONSE

EXECUTIVE SUMMARY

The plight of construction workers and their deplorable living conditions has been overlooked for the longest time. Keeping in mind the lack of welfare and the potential that lies beneath this ignorance in the form of innovative solutions and transformations, 15 students of MANIT Bhopal join in solidarity to create design solutions that conform to architectural, social, and environmental standards.

Along with incessant cooperation from our project partner- VKSC Infraprojects Limited, a trusted name in the infrastructure sector in India and synonymous with engineering excellence and integrity, we joined the Elevated Corridor project in Bhopal and worked to provide solutions for the betterment of workers on this project. To design such that the present condition of construction workers and their families sees an overall upliftment in the future scenario.

Typically, the construction workers move from one site to another in short spans of time, with or without their families. Often they encounter problems due to neglect in their living spaces, and setting up shelters due to poor modularity and planning. We looked at multiple live and secondary case studies and examples of such construction sites which helped us detail out a comprehensive list of design challenges along with the intransigent considerations of climate, energy, resilience and affordability.

On the site level, we considered both bachelors and family units, along with provisions like medical facilities, creches and communal areas for dining and recreation. The green spaces incorporated along with plantation opportunities, create a sustainable environment for the users.

On the unit level, the analysis of thermal comfort, energy efficiency and cost efficiency allowed us to choose appropriate materials and construction techniques. The chosen framing and foundation makes the unit modular while making it accessible to different climatic zones and terrains, hence an approach towards universal design.

Adhering to budget restrictions, local bylaws, and limited site resources we evolved our design through multiple complexities to arrive at a prototype that facilitates modularity, thermal comfort, water efficiency, zero dependability and scalability under market potential.

Fig no. 1

Fig no. 2

Fig no. 5

Fig no. 3

Fig no. 4

PRESENT SITE SCENARIO

2. TEAM SUMMARY

TEAM **ECONIQUE**

Institution Name: Maulana Azad National Institute Of Technology, Bhopal
Division: On-Site Construction Workers Housing

TEAM MEMBERS

Divyansh Singh
B.Arch 4th year
Team Lead

Priyansh Tirkey
B.Arch 4th year
Design Analyst

Pushpita Patel
B.Arch 4th year
Architectural Design

Rajababu Dhakad
B.Arch 4th year
Design Modelling

Ronak Mittal
B.Arch 4th year
Design Analyst

Sharashij Biswas
B.Arch 4th year
Value Proposition

Shiksha Goswami
B.Arch 4th year
Affordability

Aditi Jain
B.Arch 3rd year
Innovation

Aditi Shukla
B.Tech (civil) 3rd year
Structural Analyst

Arjita Srivastava
B.Arch 3rd year
Resilience

Mansi Yadav
B.Arch 3rd year
Embodied Carbon

Poorva Lele
B.Arch 3rd year
Sustainability

Shubham Suryawanshi
B.Arch 3rd year
Health & well being

Shyam Agarwal
B.Arch 3rd year
Energy performance Analyst

Vidya Dewaskar
B.Arch 3rd year
Water performance Analyst

Prof. Vicky Lalramsangi

FACULTY LEAD

Prof. Vicky Lalramsangi is currently an Assistant Professor in the Department of Architecture and Planning, MANIT. She is an Associate Member of IIA, Institute of Urban Designers India (IUDI), IEI (India), COA and Mizoram Architects Forum. She previously worked as an Assistant Professor in SPA Bhopal, Guwahati College of Architecture, and as a Junior Architect in the Public Works Department, Aizawl.

Dr. Anupama Sharma

FACULTY ADVISOR

Dr. Anupama Sharma is currently a professor in the Department of Architecture and Planning, MANIT. She is a member of various professional bodies like IIA, COA, IEI (India), IVVRF, VIBHA, IVS, SESI, and ISES (International Solar Energy Society). With a teaching experience of 29 years in this field, she specializes in Energy and Environmental Planning, Vastu Shastra, and Sustainable architecture.

ABOUT THE INSTITUTE:

Maulana Azad National Institute of Technology Bhopal carries a legacy of over 62 years and prides over its multidisciplinary approach toward education and producing individuals excelling in various fields of engineering and architecture. The faculties, experienced in different domains of design and architecture strive towards the holistic development of students through engaging them with various design ideologies thereby creating versatility and individualism among them.

TEAM APPROACH:

Our team consists of 15 like-minded individuals from the field of architecture and civil engineering, working towards a common goal of creating a sustainable built environment. The work division was entirely based on the skill levels and interests of the team members, thereby aiming toward a smooth workflow and efficient exchange of ideas. Further, we documented and analyzed the site that facilitated our comprehensive design strategy, which includes a deep understanding of each contest for achieving holistic results.

SOFTWARE USED

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

DESIGN MANAGEMENT PROCESS

1 Discussion with Mr. Jai Prakash Sharma (Project Manager, VKS Group), TRG members, faculty lead and faculty advisor regarding the project location, needs, and constraints. Details related to user group and the project's scope are examined.

2 Division of team members according to their forte and capabilities.

3 Studying case studies of both India and abroad for better understanding of the project.

4 Site visits and documentation helped us collect data and form our inferences in order to begin our preliminary design, conceptual ideation, and preliminary simulations.

5 To support our design in terms of sustainability, research was conducted about the possible materials with features such as durability, cost effectiveness, and heat resistance, among others.

6 Building materials, heating and cooling strategies, renewable energy systems, and energy and thermal comfort analyses were done.

7 Incorporating the 10 contests into the design concept. Using the 10 contests as a basis for exploration and simulation.

8 Achieving alignment between design proposals and digital simulations and developing a more refined proposal.

9 All the preceding processes lead to the creation of this intermediate report, which includes the entire design process.

FACULTY ADVISOR

FACULTY LEAD

3. PROJECT SUMMARY

Project Name : Elevated Corridor

Project Partner : VKSC Project Ltd.

VKS Group is a trusted name in the infrastructure sector in India. It is well known for its engineering excellence, before-time project delivery, and integrity. Promoted by second-generation entrepreneur, Mr. Vinod Kumar Shukla, the group has more than 7 decades of working experience. It is an industry leader in Central India and boasts of an incredible track record in the construction of roads and bridges, with specialization in bridge construction.

KEY INDIVIDUALS

Mr. Jai Prakash Sharma
Project Manager (VKS Group)

BRIEF DESCRIPTION OF PROJECT

With the experience of 7 decades, the VKS group is engaged in making an elevated corridor with an estimated budget of 126 crores. The structural components of the corridor are pre-fabricated and then transferred on-site. The construction of the members is done in the construction yard for which they have leased land from BHEL for 2 years at 3 lacs.
The site selected for the exercise for which we are providing solutions is the construction yard and the laborers working there. Carrying forward 7 decades of experience of VKS Group, Team ECONIQUE and VKS Group aim to provide a better and comfortable lifestyle to on-site construction workers.

SITE DETAILS

Site Location - Kasturba Nagar, Bhopal, Madhya Pradesh
Latitude- 23°13'53.06"N
Longitude- 77°26'52.15"E
Elevation-523m
Climate Zone - Composite Climate
Total Site Area (Construction yard) - 16,498.42 m^2
Permissible Built-up Area (Labour Housing)- 3150 m^2
Permissible Ground Coverage (Labour Housing) - 4950 m^2
Proposed Built-Up Area (Labor Housing) - 3150 m^2
Status of Project - On-Going Development Phase
Hours of Operation - 24 hours

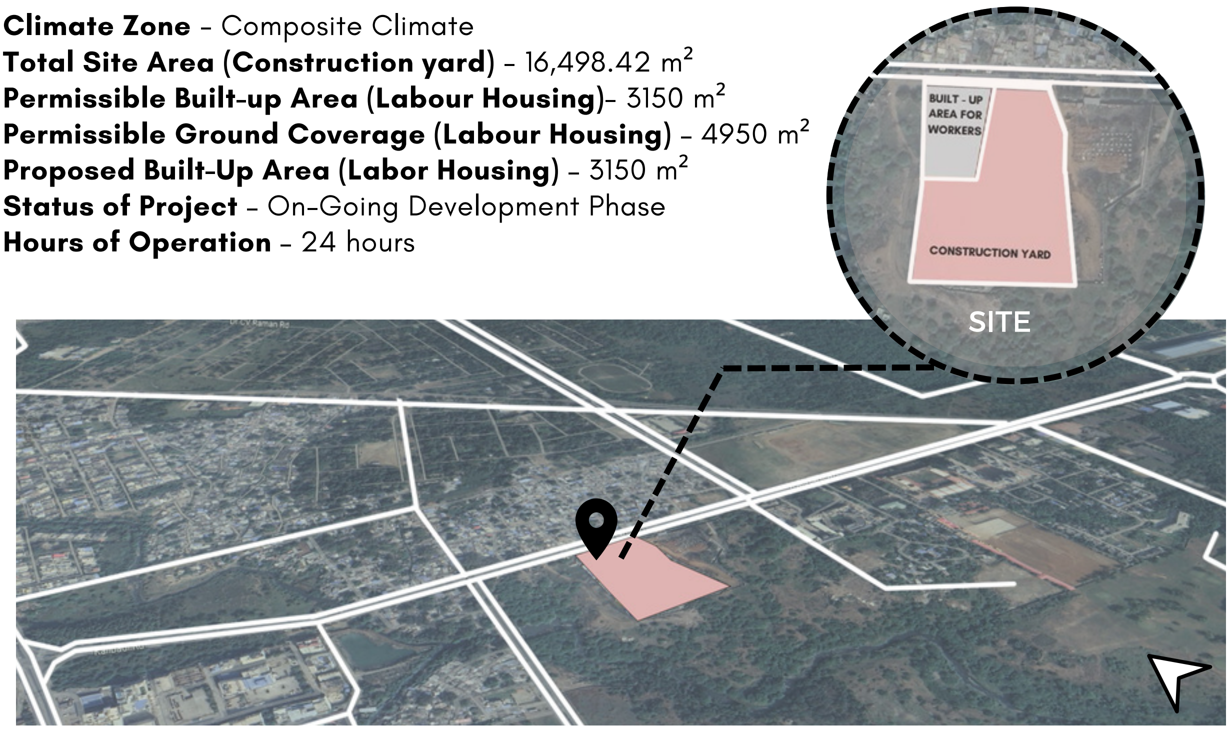


Fig no.6 Site location

SITE JUSTIFICATION

- This site has been chosen to work on as it satisfies the requirement as per the brief.
- The plight of construction workers on this site is not good at all.
- The temporary shelters are made up of tin sheets which are not suitable for the climate as well as any bad weather conditions.
- No proper fenestrations and locking provisions are provided, which makes the occupants feel suffocated residing there.
- At the time of summer, one can burn in and in winter can freeze inside the shelters.
- The floors are nothing but ground, coated with cement mortar by workers themselves in order to get thermal comfort.
- The current sanitation condition is not appropriate which should have been for the workers.
- No designated space for cooking and dining, which increases the risk of fire and children getting harmed near the cooking arena.
- We saw an opportunity of providing a better lifestyle to the workers who work so hard on construction sites.
- The project gives us enough time span and space to work, and the requirements of project partners as well as of workers meet the requirements of brief.

Fig no. 7 Unkempt platform for water usage.

Fig no. 8a Garbage, inviting diseases.

Fig no. 8b Ground covered with cement

Fig no. 9 Kitchen within the shelter with no proper provisions

Fig no. 10 Poor Sanitation and lack of space for washing cloths and utensils.

Fig no. 11 Steel reinforcement for construction kept in front of shelters which could harm the children.

Fig no. 12 Algae formation within the site near the shelters, which is unhealthy for the people living.

Fig no. 13 Tin shelters without any fenestrations seen.

SPECIAL REQUIREMENTS OF CLIENTS

When we reached out to the client, the client came up with some special requirements which are mandatorily needed in the project. The following are the requirements stated by the client:

- Childcare spaces
- Thermal comfort
- Healthcare services
- Hygiene
- Lighting and ventilation

SPECIAL REQUIREMENTS OF PROJECT PARTNER

During the discussion with the project partner many issues were discussed regarding the construction worker housing keeping in mind some essential factors, and as a conclusion to the discussion following are the requirements stated by the project partner.

- Affordability
- Single floor construction
- Ease of installation
- Low Maintenance cost
- Quality shelter
- Recyclable
- Low transportation cost
- Proper Water Management
- Durable
- Low wastage of water

OCCUPANTS DETAILS

Profile Of Occupants - Labors (Carpentry, Masonry Workers, Skilled & Unskilled Labors)

Operational Hours - 16 hrs.

Homeland -

Labors on the construction site are from 4 states of India i.e. Bihar, Jharkhand, West Bengal and Uttar Pradesh.

Age Group -

Different age groups are living together here, they are categorized as below :

- Age group of 21 years to 40 years - 120 people
- Age group of 40 years to 50 years - 20 people
- Age group of 50 years to 60 years - 20 people

Working Hours -

The working hours for the labours on site are from 10am to 6pm and from 7pm to 5am.

User Activities -

On closely studying the schedule of the labourers, their daily activities are noted and are listed below.

Fig no. 14 User activities.

CONSTRUCTION COST

Preliminary Construction Budget Per Unit - **Rs.89060/unit**

Preliminary Construction Budget per Square meter - **Rs.4453/m^2**

4. GOALS

ENERGY CONSERVATION

GOALS
To reduce EPI to be **22 kWh/m²/ year.**

STRATEGIES

- Incorporating renewable energy methods like solar PV system, wind turbines etc.
- Maximizing energy saving by optimizing energy usage in the building, exploring energy efficiency devices and implementing natural local cooling solutions.

WATER PERFORMANCE

GOALS
To Reduce water consumption by **20-40 %**

STRATEGIES

- Incorporating Grey Water treatment system, rain harvesting system to optimize on-site water savings.

RESILIENCE

GOALS
The design should be able to combat natural and manmade disasters and yet maintain its function to its fullest in face of stress.

STRATEGIES

- Providing rechargeable batteries to withstand natural/ manmade Disasters.
- Incorporating interchangeable Design Solutions to adapt to changing environmental conditions as well as other potential dangers like endemics, pandemic and industrial hazards.

AFFORDABILITY

GOALS
To minimize building and installation costs.

STRATEGIES

- Use of contextual and economical materials.
- Reduce the maintenance costs of the units.

INNOVATION

GOALS
To get exposure of more modern creative methods and approaches.

STRATEGIES

- Modular scalable modules are constructed using simple joinery materials that facilitate structure construction.
- Allowing the design elements to be customizable for the end users by incorporating foldable and scalable furniture, thus adapting a user-oriented approach.

HEALTH AND WELL BEING

GOALS

To ensure thermal and mental comfort, improve indoor air quality and to provide a healthy indoor environment to all its users.

STRATEGIES

- Providing thermal insulation, operable shade mechanisms and proper window size.
- Incorporating Passive ventilation techniques such as stack effect, cross ventilation and natural ventilation
- Using tranquilizer Colour paints making design adaptable to human demands, behaviors, and requirements.

ENGINEERING AND OPERATIONS

GOALS

Blending our architectural vision with structural integrity.
Planning and designing for proper and appropriate mechanical systems.

STRATEGIES

- Offering a floor level one feet above the ground to address moist soil concerns in the rain, hazardous health problems, and cleanliness.
- Providing adjustable footing to tackle terrain problems and avoid land cutting.

ARCHITECTURAL DESIGN

GOALS

To achieve a level of aesthetic appearance with proper functionality.

STRATEGIES

- Designing units to maximize day light throughout the year and minimize energy consumption in the early hours;
- Developing units to be adaptable to diverse climatic conditions (with minor alterations); and providing alternative cluster choices depending on the site.

VALUE PROPOSITION

GOALS

To produce an end product that is user-friendly, economical, and sustainable.

STRATEGIES

- Avoiding carbon-emitting materials and exploring materials suitable in different climatic conditions (for modification)
- To employ recyclable materials like steel, bamboo, etc.

EMBODIED CARBON

GOALS

To reduce on-site carbon production as well as to reduce the carbon released by the vehicles during the transportation of materials from the site of production to the site of construction.

STRATEGIES

- The production site should be located near the construction site to reduce the distance of transportation and thus reduce the carbon generated by the vehicle.
- Carbon catchment areas can be provided throughout the site to minimize overall carbon generation over time.

5. DESIGN PROCESS

5.1 DESIGN CONCEPT

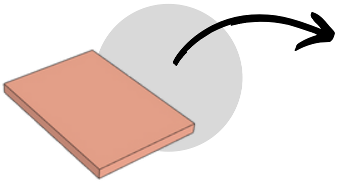
• We want to build accommodation for the workers that is more than just a row of sheds and includes well-planned, hygienic common areas.
• The central open courtyards are large enough to be used as community gathering areas, operate as accelerators for the improvement of natural light, and offer a pathway for natural ventilation.
• Units are planned so that they face all directions to foster a sense of community and to take advantage of natural lighting and wind flow.

SPACE DIVISION

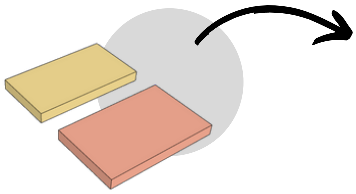
PUBLIC AREAS	SEMI PUBLIC AREAS	PRIVATE AREAS
Service rooms	Recreational area	Residential unit
Medical room	Storage room	Washrooms
Creache	Dining	Bathing
Office	Kitchen	
Farm land		

5.2 SITE ZONING

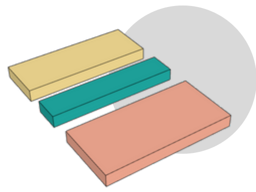
The site is divided into different zones according to the level of privacy, spaces for recreational purposes, and provisions for basic utilities. Considerations were taken for accessibility, ventilation and natural light while dividing spaces.



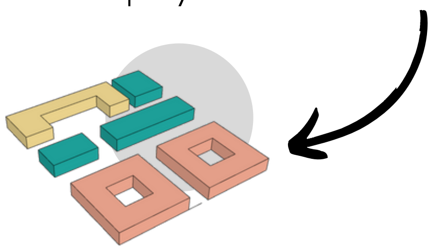
1. A low rise mass was taken according to the restricted site volume and context.



2. The mass was divided into two clusters of residential purposes.

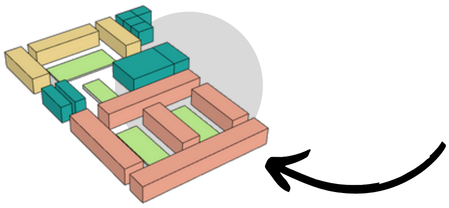


3. A Separate space was taken out for recreational and service areas equally accessible.



4. Further massing of spaces were done to create courtyard like green spaces for ventilation and natural light.

FAMILY UNIT
BACHELOR UNIT
SERVICE UNIT

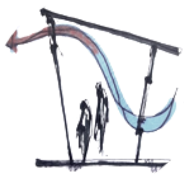


5. This space division was created according to the requirements for the final zoning.

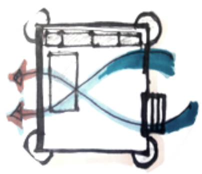
5.3 PASSIVE DESIGN STRATEGIES

Operable louvers are introduced for natural daylight.

Upper flap used for collecting rainwater. Rainwater collected from the roof is treated and used for washrooms.



Operable louvers are used for stack ventilation.



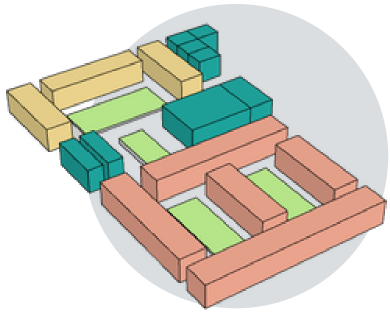
Bigger openings for intake of natural light and ventilation are provided for each unit.

6. DESIGN DOCUMENTATION

6.1 ARCHITECTURAL DESIGN

6.1.1 SITE PLAN

The total usable site area was taken as 3150 m^2 as per the housing requirements. The site was further divided into public, semi public and private spaces with green spaces incorporated in between. Housing modules were divided on the basis of members- bachelor units and family units. Facilities are provided such as creche, communal dining area, public washrooms, medical room, and other crucial services.



LEGENDS

1. FAMILY UNITS
2. BACHELOR UNITS
3. ELECTRIC SERVICE ROOM
4. STORAGE
5. OFFICE
6. MEDICAL ROOM
7. DINING HALL
8. KITCHEN
9. RAINWATER TANKS
10. WATER STORAGE TANK
11. WASHROOMS
12. ROOT ZONE PLANTATION
13. GREEN SPACES

Fig no. 15 Site plan

AREAS	AREA PER UNIT IN m²	NO OF OCCUPANTS	NO. OF UNITS	AREA IN m²
BACHELOR'S UNIT	20	4	30	600
FAMILY'S UNIT	20	3	12	240
BATHROOM	1	1	10	10
TOILET	1	1	10	10
KITCHEN	50	-	1	50
DINING	130	50	1	130
SERVICES				
MEDICAL ROOM	20	-	1	20
CREACHE	20	10	1	20
OFFICE	20	2	1	20
ELECTRIC SERVICE ROOM	20	-	1	20
STORAGE ROOM	20	-	1	20
TOTAL AREA	-	-	-	1110

6.1.2 UNIT PLAN AND SECTION

The modules designed are easy to dismantle and reassemble as per the requirements. Modules of both bachelor's and families constitute of same basic structural details with some minute changes in furniture layouts as per the requirements of both the user groups.

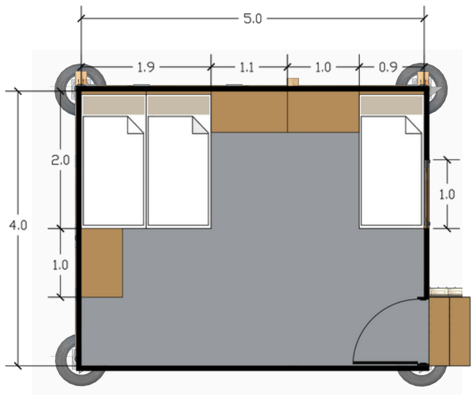


Fig no. 16 Family unit.

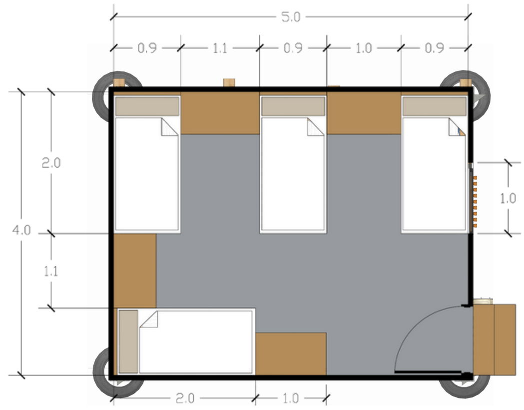


Fig no. 17 Bachelor unit

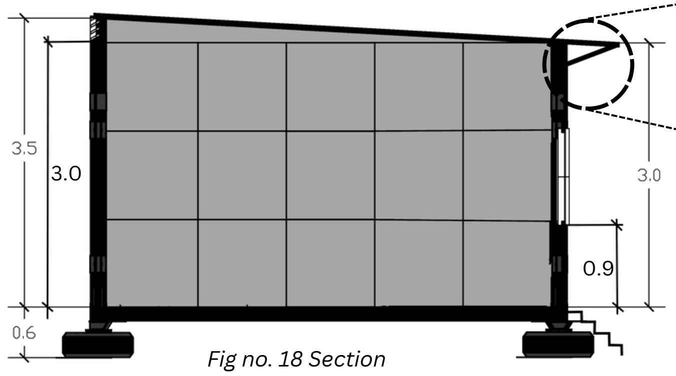
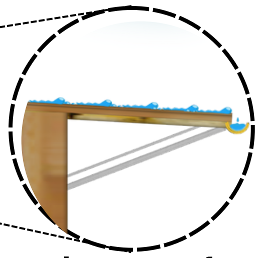


Fig no. 18 Section



Each unit has a **sloping roof** system with a **window and ventilator with louvers** which allows stack effect in the unit. The sloping roof also contributes to rainwater harvesting.

SITE VIEW

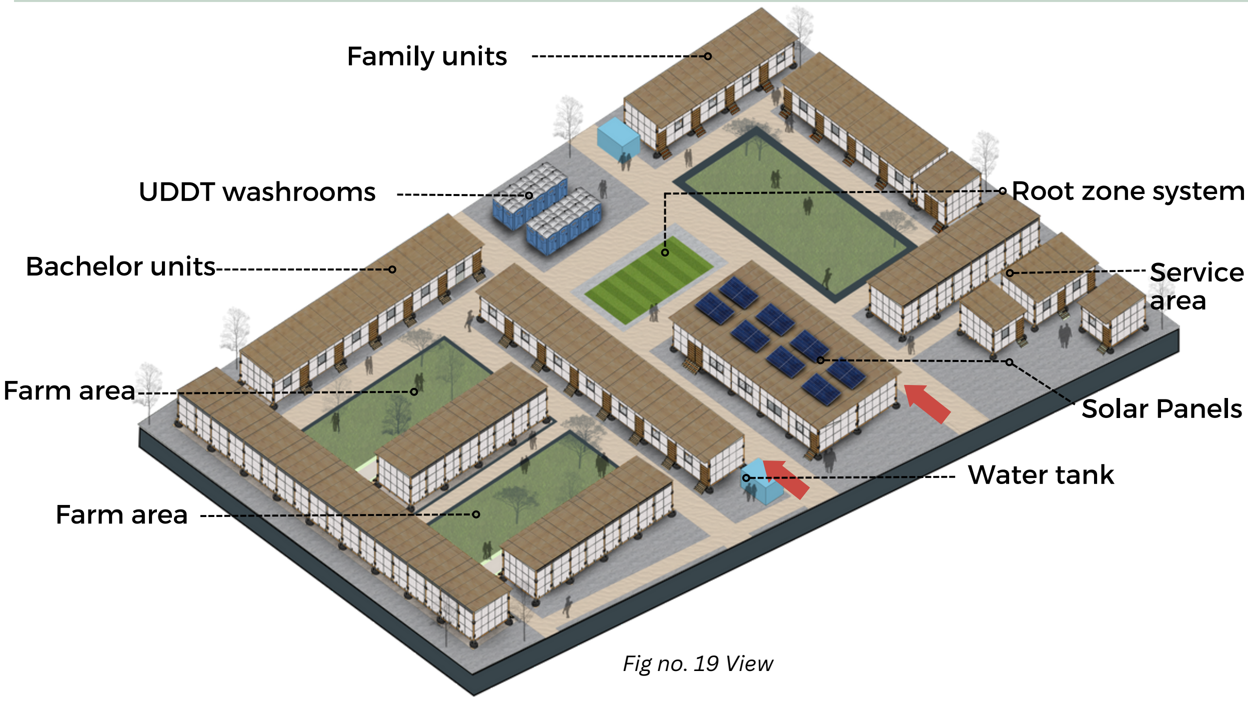


Fig no. 19 View

6.1.3 ELECTRIC AND FIRE LAYOUT

In this layout, we can see how the electric connections are laid off on the site and the placement of fixtures in the unit plan.
The on-site electric room is located on the northeast side and transfers electricity to various parts of the site, including the family unit zone, bachelor unit zone, kitchen and dining area, toilets, and service area through MCB.
The unit plans show the layout of electric fixtures (two tube lights and one fan in each unit). The electricity required to run appliances and fixtures is generated on the site itself with the use of solar panels.

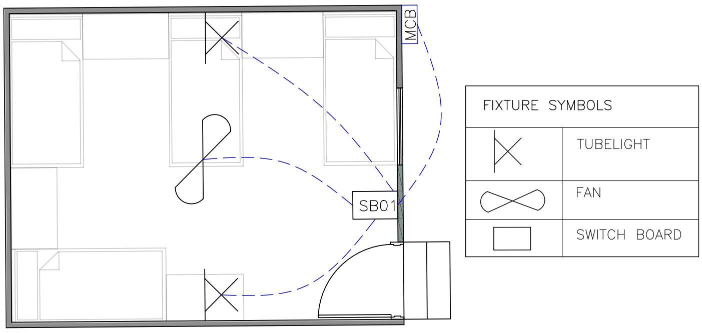


Fig no. 20 Unit electrical layout

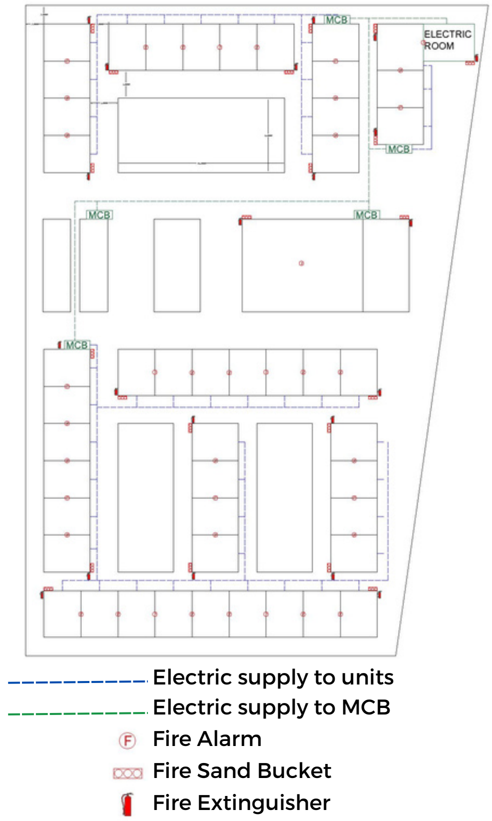


Fig no. 21 Site electrical and fire layout

6.1.4 SITE WATER SUPPLY LAYOUT

In this layout, the water supply pipelines can be seen. Municipal supply is taken and used for the preparation of food and drinking water. The greywater generated is reused through root zone system and the outlet from reed bed tank is used for flushing purpose.

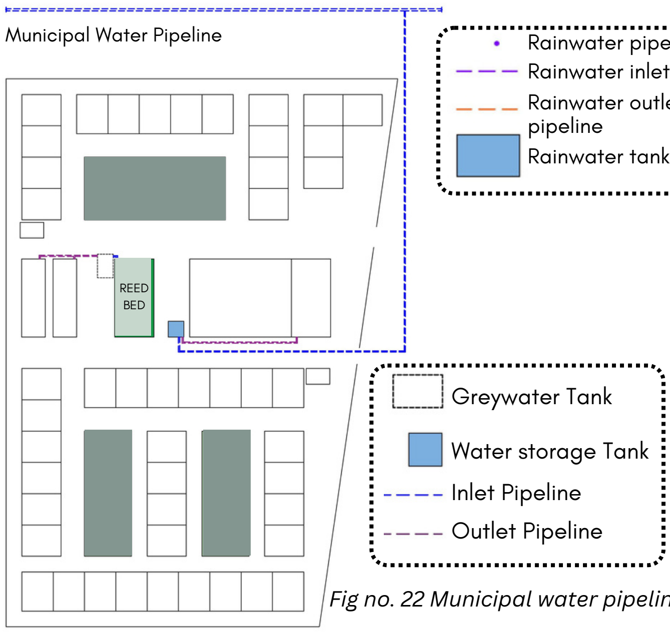


Fig no. 22 Municipal water pipeline

6.1.5 RAINWATER HARVESTING LAYOUT

In this layout, the rainwater collected from site area is being stored in rainwater tanks which would be treated and reused for daily activities like bathing, cooking, etc.

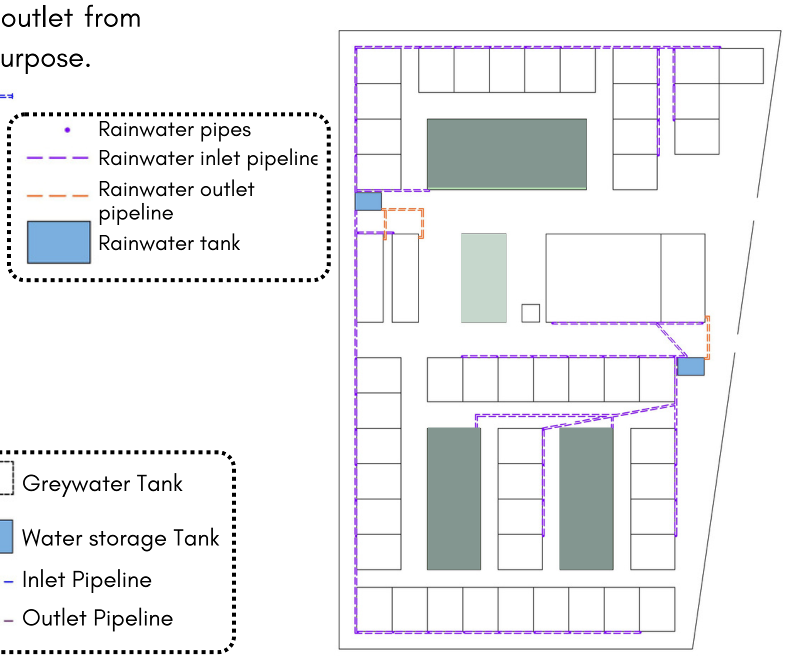


Fig no. 23 Rainwater harvesting layout

6.2 ENGINEERING AND OPERATION

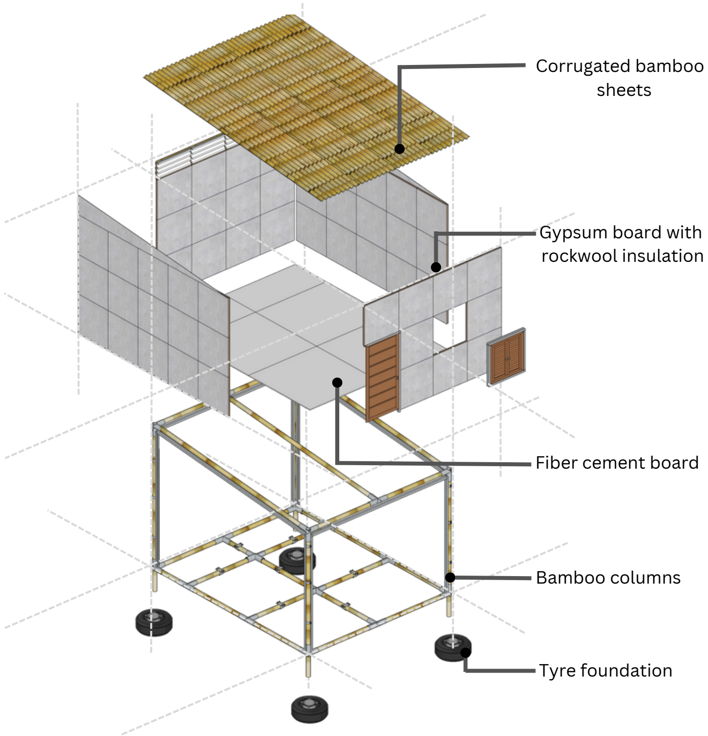
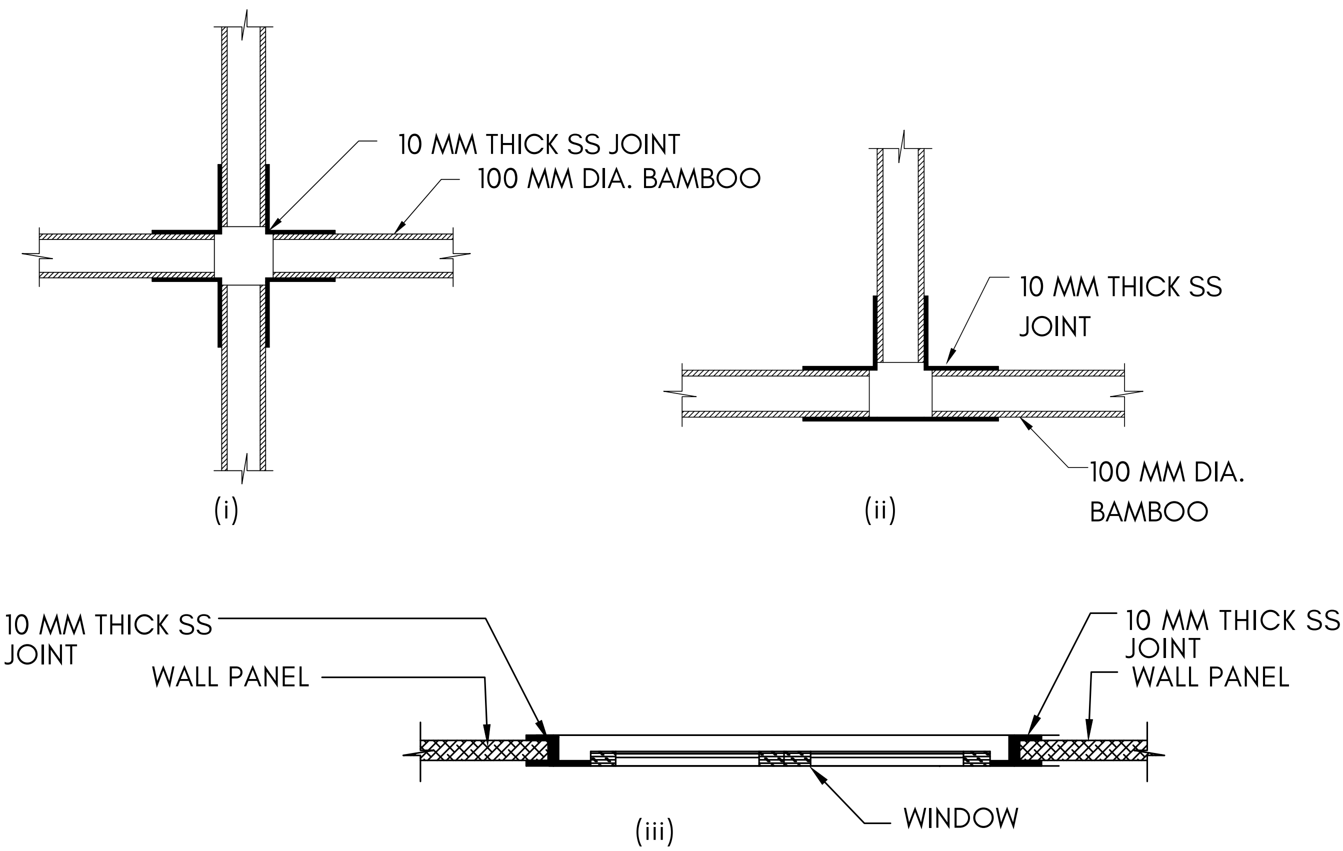


Fig no. 24 Exploded view

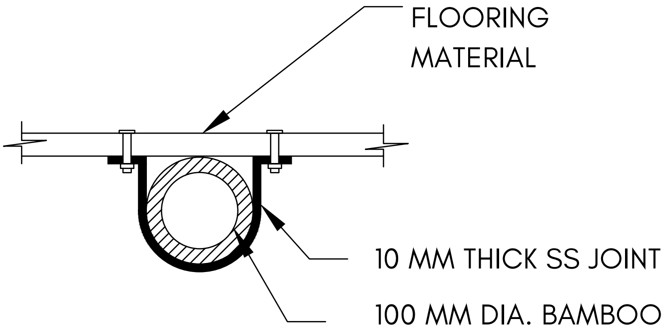
The individual elements of the unit functions together to solidify the structural integrity of the unit. The tyre foundation is a sustainable alternative for different terrains while the corrugated bamboo roofing along with bamboo joinery possess great internal strength and resists weathering and fire. The walls provide sufficient insulation through rockwool sandwiched with gypsum board, thereby giving thermal comfort.

The tongue and groove technology is used to install recycled fibre cement board, which does not require the use of adhesives.

6.2.1 JOINERY DETAILS



6.2.1 JOINERY DETAILS



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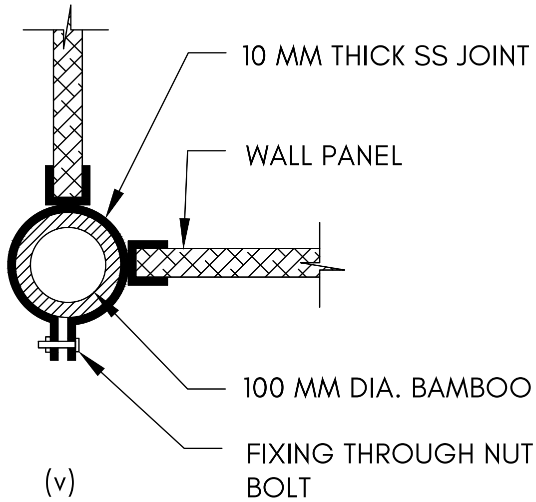

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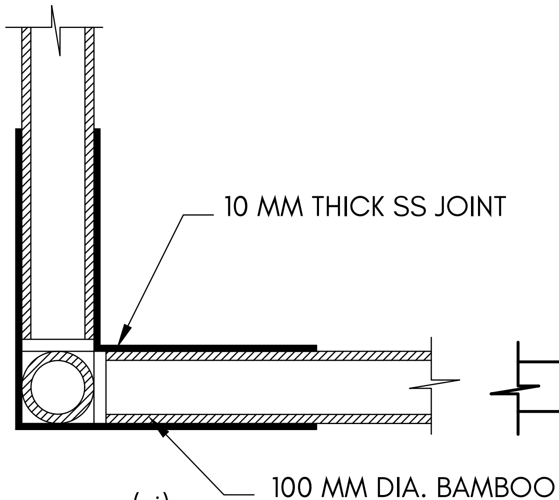

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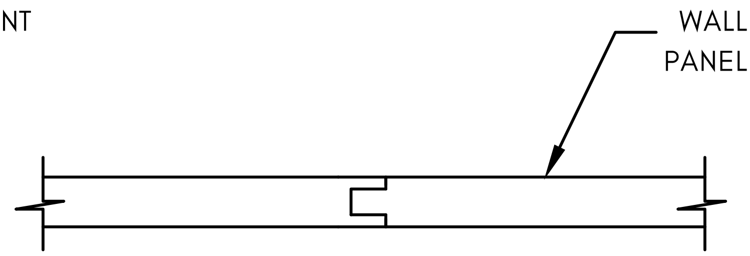
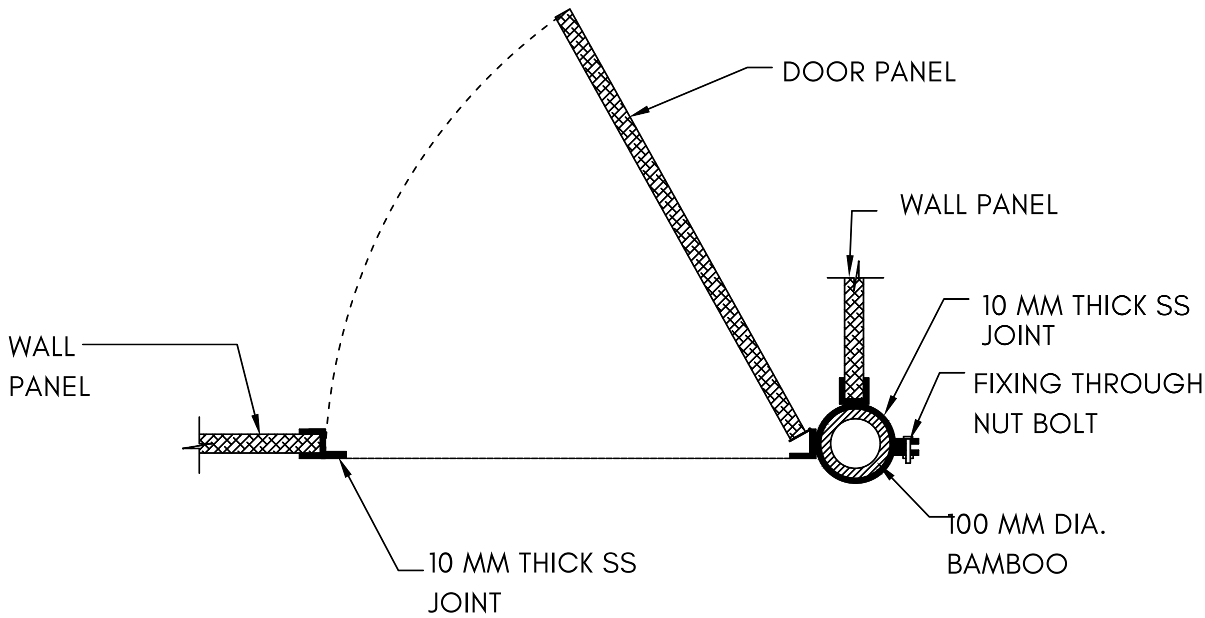


(vii)



(viii)

6.2.2 STRUCTURE DETAILS

LOAD DISTRIBUTION :

The load distribution pattern for different loads (including all the types of dead loads and live load) on structure is shown below:

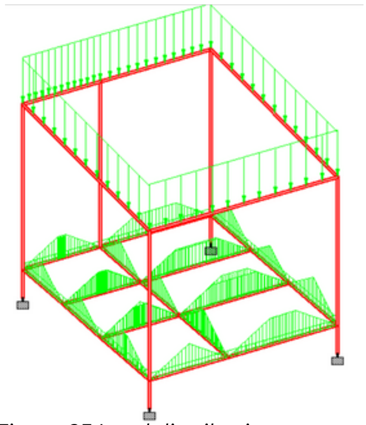


Fig no. 25 Load distribution

LOADS ON FOUNDATIONS :

The reaction allows us to examine different types of forces and their components acting. The reactions at different ends(foundations) of the structure are shown below.

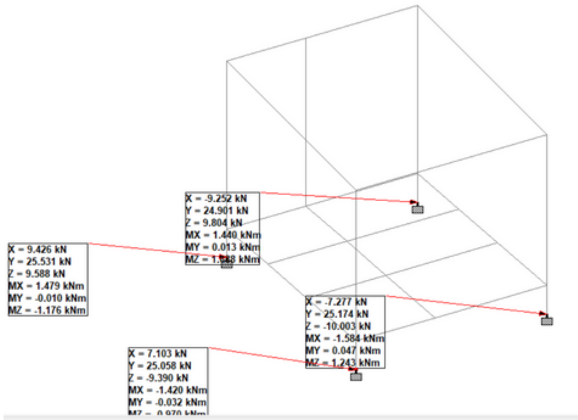


Fig no. 26 Nodal Reactions

DEFLECTIONS IN THE STRUCTURE :

The structure's deflection diagram, which informs us of the deflection nature of the plinth beams and beams after the application of an appropriate load to the structure, is displayed below.

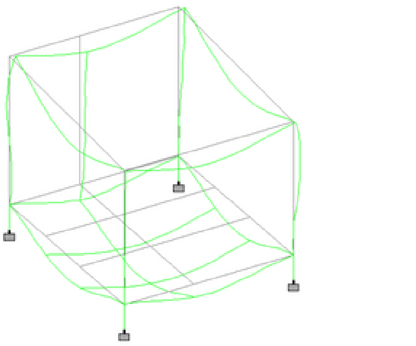


Fig no. 27 Deflections in the structure

SHEAR FORCE AND BENDING MOMENT :

The shear force and bending moment diagram shown below allows us to understand the shear forces and bending moment of the structure as a reaction to the loading conditions of the structure.

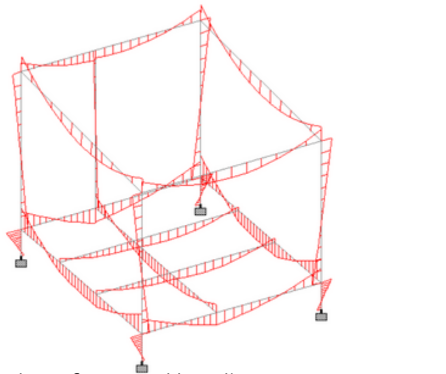


Fig no. 28 Shear force and bending moment

Maximum deflection in the beams:
Max(mm)=60.632mm

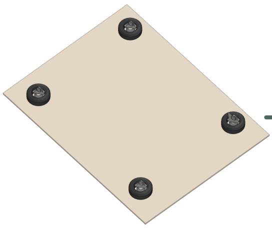
The Maximum shear force(kN):Fy= 14.628.

The maximum bending moments= (kNm):
Maximum hogging moment=8.199(+ve)
Maximum sagging moment = 5.5203(-ve)

CONCLUSION OF STRUCTURAL ANALYSIS :

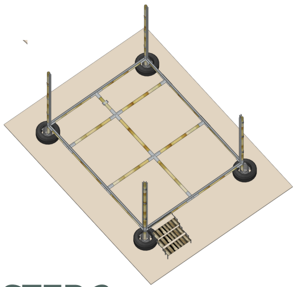
From the above structural analysis, we can conclude that the **unit is safe from the dead loads and possible live loads** and is represented in the above figure shows the structural analysis for the unit and helped in understanding the load transfer mechanism through which we know that our module is structurally stable.

6.2.3 UNIT INSTALLATION



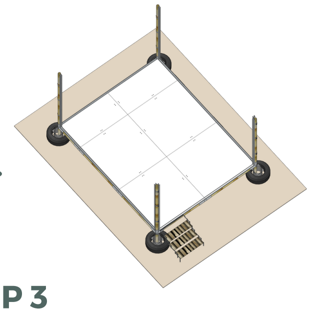
STEP 1

Laying of the foundation – Tyre Foundation



STEP 2

Bamboo attached to the foundation to create a frame for the unit.
Bamboos are joined with the help of steel sections.

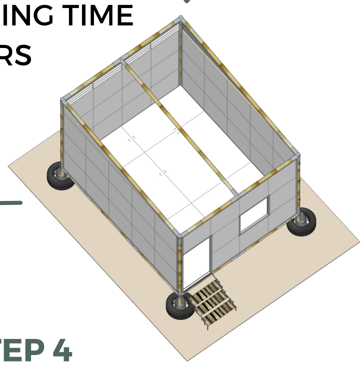


STEP 3

Floor panels are fixed using plate with screw and bolts.

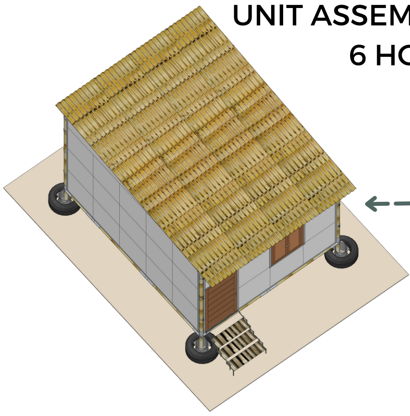
The initialization of assembling the unit was to lay the foundation, for which we have used tyres for load distribution and stability, an economically sustainable alternative for the conventional heavy foundation. The foundation is laid after which the structural frame is created with bamboo pipes attached through the foundation. The joinery unit between bamboo and tyre is such that it can be adjusted at different heights, according to the terrain.

UNIT ASSEMBLING TIME
6 HOURS



STEP 4

Sandwich panels for walls are connected to each other by tongue and groove joint and attached to the unit through panel joints and top panel joints.



STEP 5

Attaching the doors, windows and bamboo mat corrugated sheet roof.

GENERAL INSTRUCTIONS

To ensure that all workers can understand and be aware of the guidelines for their well-being, we will provide a guide in a way that is accessible to those who may not be literate.This will involve creating pamphlets with clear instructions in vernacular languages that are commonly spoken by the workers.

Additionally, we will install many signboards throughout the premises of the CWH that indicate local guidelines, hazards, and necessary precautions.

To further ensure that all workers can access this information, we will provide affordable low wattage horn speakers in areas where workers regularly gather, such as community and dining spaces. This will allow us to regularly pass on instructions and messages, providing important information to those who cannot read or interpret signs.

6.3 AFFORDABILITY

6.3.1 MATERIALS- COMPARATIVE ANALYSIS

Given below is a comparative analysis of the potential materials and materials chosen for the units. The materials are chosen according to their cost, strength, thickness, U value, workability and other factors as mentioned in the table.

Element	Walls-			Flooring			Roof			Structural Frame	
Material	PUF panels	Gypsum board with Rockwool insulation panels	PET bottle with cement plaster	GI sheets without insulation	Fibre cement board	Concrete panels	Tetrapack	Bamboo Mat Corrugated Sheet	MOD Roof	Steel	Bamboo
Cost per sqm	Rs 1350	Rs 356	Rs 230	Rs 360	Rs 700	Rs 1200	Rs 300	Rs 340	Rs 600	Rs 500 per piece	Rs 210
Strength	380.25	16+0.02	220.15	245	24.2	45.9	15	39.72	4.9	44.36	44.36
U value	0.297	0.56+0.25	2.541	5	0.430	0.833	0.035	5.6	0.28	1.2	1.4
Thickness	30-100mm	45mm	50mm	0.45-2mm	20mm	130mm	4mm	5mm	3mm	-	60mm
Moisture Resistance	●●●	●●●●	●●●	●●●	●●●●	●●●●	●●●●	●●●●	●●●	●●●	●●●
Fire Resistance	●●●●	●●●	●●	●●●	●●●●	●●●●	●●●	●●●●	●●●●	●●	●●●●
Workability	●●●	●●●●	●●●	●●●●	●●●●	●●●	●●●●	●●●●	●●●	●●●	●●●●

- **Material- WALL**

Assembly of gypsum board of thickness 12.5mm with rockwool insulation of 25 mm thickness will be used as wall material.

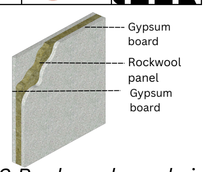


Fig no. 29 Rockwool sandwiched with gypsum board

- **Material- FLOORING**

Fiber cement boards are composite materials made of sand, cement and cellulose fibers. More specifically, they are composed of Portland cement with glass-fiber mesh on the surface.

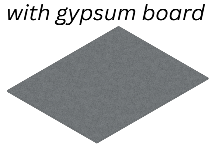


Fig no. 30 Fiber cement board

- **Material- ROOF**

Corrugated bamboo roofing sheets (CBRS) are an excellent alternative to corrugated metal, plastic, or asbestos roofing sheets. They are produced from a natural and sustainable resource and can be used to cover homes, storage facilities, and many other temporary or permanent structures.

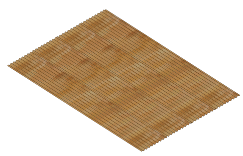


Fig no. 31 Corrugated bamboo

- **Material- STRUCTURAL**

Bamboo frames are an excellent alternative to metalor plastic. They are produced from a natural and sustainable resource and can be used to cover homes, storage facilities, animal pens and many other temporary or permanent structures.


Fig no. 32 Bamboo frames

6.3.2 AFFORDABLE - STRATEGIES

- Design strategy that is used for optimizing the cost of construction is simple modular construction. **Modular construction projects may be construction 30%-50% times faster than the conventional construction methods.** It also produces less building waste, lowering material cost.
- To reduce the cost, we have used foldable bed as it is cheaper and require less space.
- We have also used solar lights in place of normal tube lights which are made of plastic water bottles that free of cost.
- The module can be easily constructed and dismantled anywhere, easy to handle and can easily transportable, therefore making it affordable.
- Tyre was used in the foundation of the buildings in the project which are reusable tyres that reduce that cost by 90%.
- For a period of, say, 10 years, **UDDTs are more economical alternative**, since the emptying of feces vaults is simple and safer, thus less expensive.
- While constructing such a toilet costs ₹ 20,000, it saves anywhere between 8-10 liters of water per use. Low capital and operation costs.

- Urine Diversion Dry Toilets

Economical | User-acceptability | Easy-installation | Do not smell | Balance cost

- Tyre-Foundation:

Adjustible | Low-tech | Earthquake resistant | Availability | Re-usable

- Multi-purpose furniture:

Maintenance | Compact | Save space | Flexible | Low cost

- Rain water harvesting:

Water bill reduction | Recharging groundwater | Preventing soil erosion | Energy-conservation | Simple and easy installation

6.4 INNOVATION

6.4.1 BIO-GAS SYSTEM

- The bio-sanitation system aids in the disposal of human waste in a 100% eco-friendly approach.
- The technique produces colourless, odourless, and combustible biogas that may be used for cooking.
- It also produces nutrient-rich, odourless recycled water that may be used in landscaping.

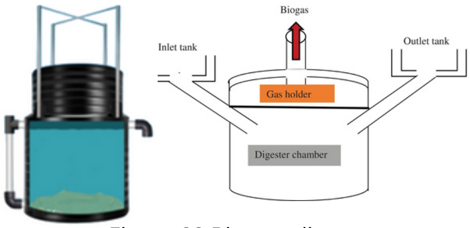


Fig no. 33 Bio-gas digester

6.4.2 TYRE FOUNDATION

Rubber 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.
- 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.

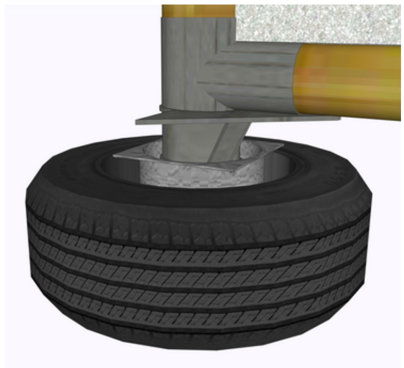


Fig no. 34 Tyre foundation

6.4.3 URINE DIVERSION DRY TOILETS

A urine-diverting dry toilet (UDDT) is a type of dry toilet with urine diversion that can be used to provide safe, affordable sanitation in a variety of contexts worldwide. The separate collection of feces and urine without any flush water has many advantages, such as odor-free operation and pathogen reduction by drying.

Advantages of Urine diversion dry toilets:

- Double vault Urine Diversion Dry Toilets (UDDT) can be used as an alternative to pit latrines in refugee camps.
- They utilize two chambers for faeces, one of which is in use whilst the other is full and drying so UDDTs can be used indefinitely, which can result in them being more economical than pit latrines which need periodic replacement every two - three years.
- UDDTs are relatively easy and safe to empty using only a spade, and much easier to empty than pit latrines. UDDTs do not smell, which is a frequent problem with pit latrines.
- UDDT toilets contribute to environmental protection by reducing the pollution of water bodies through wastewater discharge.

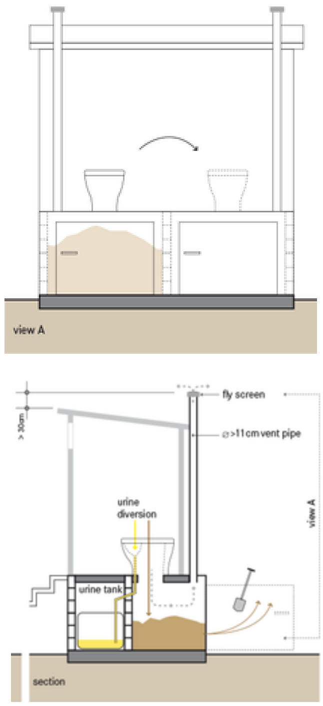


Fig no. 35 UDDT

6.4.4 WALL PANEL

The wall panel is made using gypsum board and rock wool. Rockwool is sandwiched between two gypsum board panels. Thus, the Rockwool panel acts as an insulation material that restricts heat transfer inside the units. 1000mm X 1000mm prefabricated panels will be joined using tongue and groove joints.

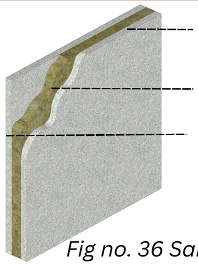


Fig no. 36 Sandwiched panel

6.4.5 ROOT ZONE TREATMENT

The term root zone encompasses the life interactions of various species of bacteria, the root of the wetland plants, soil, air, sun and of course, water. Root zone treatment is one of the natural and attractive methods of treating domestic, industrial and agricultural wastes and purifying wastewater as it passes through artificially constructed wetland area.

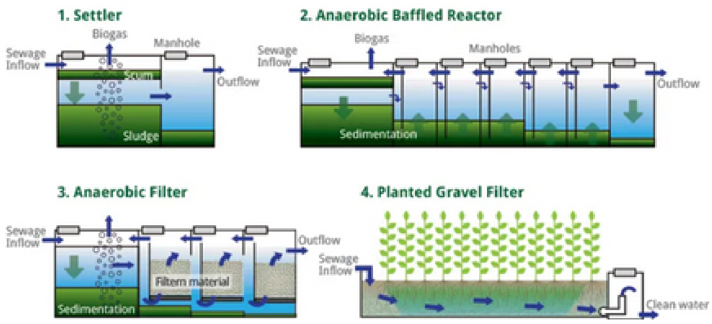


Fig no. 37 Root zone treatment

Advantages of root zone treatment:

- It achieves standard for tertiary treatment with low costs, such as no electricity, no chemicals for pH adjustment.
- The maintenance cost is low since it involves no machinery and its maintenance.
- Negligible attendance for operation and monitoring.
- It has no sludge handling problem.
- It enhances the landscape and gives the site a green appeal.

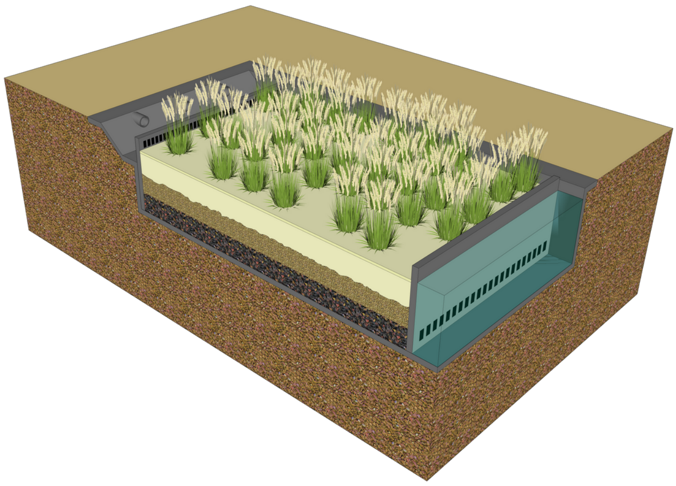


Fig no. 38 Root zone treatment

6.4.6 ECO-COOLERS

- A board is shaped to fit the required window, and grid-like tiny holes are drilled into it.
- The terracotta pots are made in the shape of funnels and set on a grid. When the pots are mounted, the broader portion faces outward and captures the wind, literally funneling cold air into the interior of the building.
- The terracotta material absorbs the heat from the air and radiates it out through the pot's porous surface.

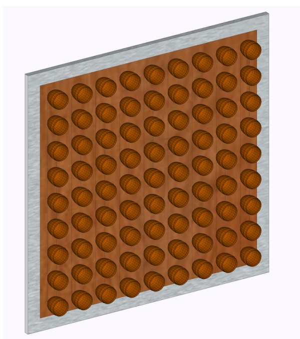


Fig no. 39 Eco-cooler

6.5 HEALTH AND WELLBEING

Since our site come under the composite climatic zone, it is imperative to utilise natural ventilation and lighting as much as feasible.

6.5.1 RADIATION ANALYSIS

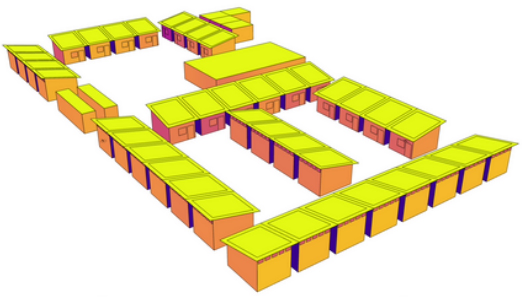


Fig no. 40 Radiation analysis

Observations-

- Roof surface radiation values are almost constant for all the months i.e., **135-200kWh/m²**. High roof used for solar panel placement.
- Openings are given in both directions as heat gain is less and diffused light gain is greater.

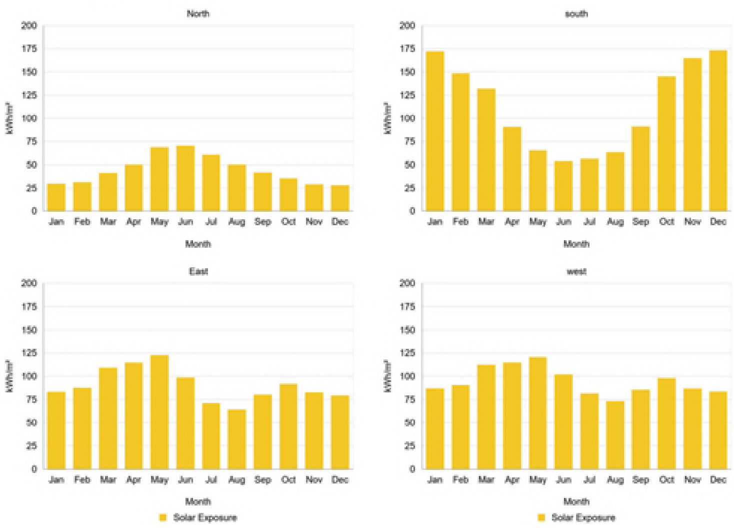


Fig no. 41 Solar exposure

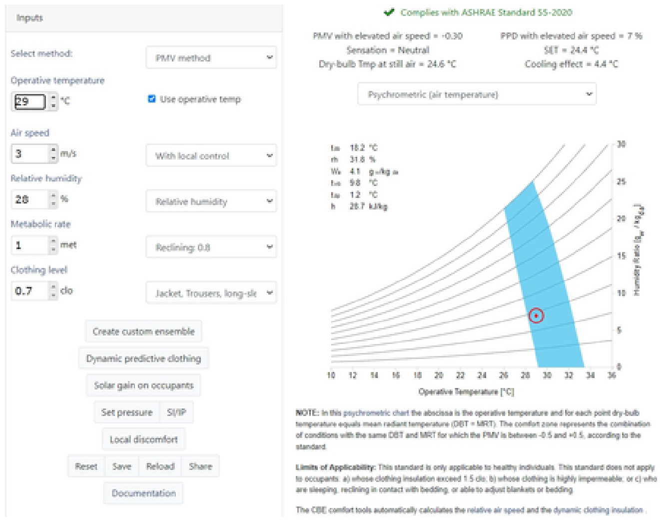
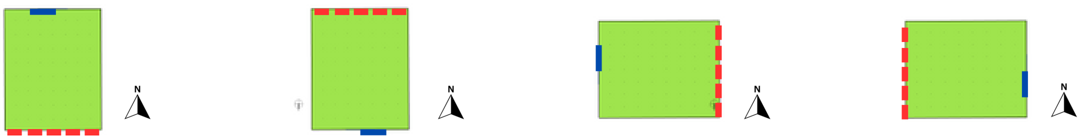


Fig no. 42 Complies with ASHRAE_Standards 55-2020

6.5.2 DAYLIGHT ANALYSIS

Floor plan of module was placed in all 4 directions to check which direction serves best daylight result for the module.

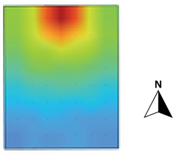
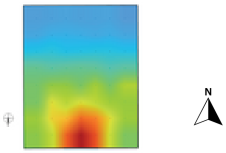
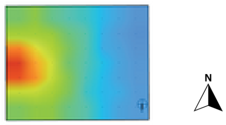
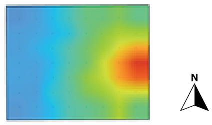


Blue line represents window.
Red dotted line represents operable louvers.

Observations-

- The green portion indicates the area which gains **300 lux** of natural light at least 50% of the day.
- Thus, from the above result, it is clear that openings are given such that in all for orientation our module gains sufficient natural light. This minimizes the use of artificial light in the day time and **saves energy up to 50 %.**

6.5.3 ILLUMINATION ANALYSIS

Observations-

- Since there isn't an even dispersion of light across the module, additional LED lights must be installed there to give enough illumination for nighttime vision.
- Where there is less light, in the blue sections, is where the LED lights will be provided.

6.5.4 THERMAL COMFORT

Space type	No. of occupant	Rp(l/s.person)	Floor area(m^2)	Ra(l/s.m^2)	ventilation rate(l/s)
Dormitories	4	2.5	20	0.3	16
Housing	3	2.5	20	0.3	13.5
Kitchen	5	3.8	50	0.6	49
Medical room	4	8	20	0	32
Creche	10	5	20	0.9	68
Dining	50	3.8	130	0.9	307

Fig no. 43 Ventilation rate for different spaces

Space type	Required ACpH
Dormitories	4
Housing	4
Kitchen	15
Medical room	8
Toilets	6
Bathroom	6
Dining	10

Fig no. 44 The ACpH(Air Change Per Hour) Standard as per nbc

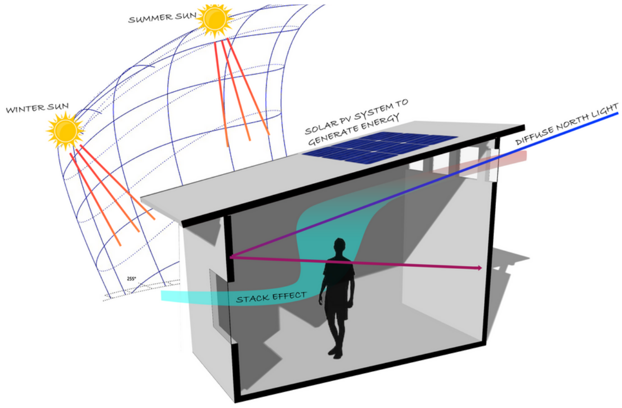


Fig no. 45 section of module explaining climate strategy implemented

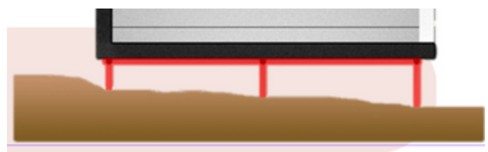
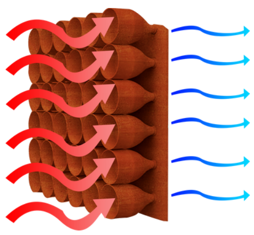


Fig no. 46 Adjustable footings to prevent as much land from being excavated and filled in.



This Jaali made from terracotta can be replaced in summer with module windows to cool down the hot air by the venturi effect. The outside part has a large diameter opening to catch more air and the inner side has a small dia opening to compress and cool down the air. This lower the air temperature by 4 - 6 degrees Celsius and its efficiency can be further increased by pouring water. This saves the cooling energy consumption.

6.6 RESILIENCE

6.6.1 PREVAILING RISKS IN THE LOCATION

As Bhopal lies in central India it does not face extreme weather conditions.

- **Drought:** As per the data of the Madhya Pradesh disaster management authority, Bhopal has faced drought in the past and comes under a region that is prone to drought-like conditions.
- **Flash floods:** With urbanization, the instances of flash floods all around the globe are increasing. It is turning into one of the frequently faced calamities and is arising as one of the major concerns. Bhopal is also susceptible to flash floods and experiences frequent cases of flash floods.
- **Heat waves:** The advent of heat waves has adversely affected the whole world and India.According to a report by Lancet, India's vulnerability to extreme heat increased by 15% from 1990 to 2019. The five warmest years ever recorded in India have all been in the last decade. The site comes under the region affected by heat waves.
- **Other hazards:** Apart from these, fire, pandemic, and social security are some of the concerns which need our due attention.

6.6.2 HAZARDS AND THEIR MITIGATION

DROUGHT	FLASH FLOOD	HEAT WAVES	FIRE HAZARD	IMPACTS OF DISASTER		MITIGATION MEASURES
				Strain on food security		Proper food reserves are provided.
				Endangers health and hygiene / fatal to human life		Medical facilities are provided.
				Not enough Drinking water		On site water reserve is provided.
				Migration or Relocation		Modular scalable modules facilitate easy construction and reconstruction

DROUGHT	FLASH FLOOD	HEAT WAVES	FIRE HAZARD	IMPACTS OF DISASTER		MITIGATION MEASURES
				Flooded sewage networks can lead to back flow of sewage		Sewer backflow valves are incorporated.
				Collapse of transmission lines/ Strain on energy		On site energy reserve Mitigating measures like solar panels are incorporated.
				Rupture of water pipes/ increased strain on water reserve		On site water reserve. Techniques like Rain water harvesting are incorporated.
				Uncomfortable rise in Temperature		Passive ventilation techniques and technologies like adjustable louvers are used.
				Combustion and damage of timber structure and flammable material in a building		Fire hose, fire extinguisher and sand buckets. Flame retardant materials.

PANDEMIC

- **Isolation Wards :** To tackle the situation of pandemic, the modules can also act as an isolation ward for the infected people at a secluded space. The furniture arrangement would be different in the scenario and would be according to COVID 19 norms.

6.6.3 RECOVERY PLAN

Steps taken after disaster hits :

- Need of medical facilities.
- Transportation to nearby hospital.
- Replenishment of all the reserves.
- Replacing and recovering components due too structural damages.
- Dismantling of modules and resettlement of people.

6.7 ENERGY PERFORMANCE

The energy performance index (EPI) is the total energy consumed in a building over a year divided by the total built-up area and is considered as the simplest and most relevant indicator for qualifying a building as energy efficient or not. EPI is the energy used per unit area measured as kWh/m^2/year or kWh/person/year.

The EPI for the project was reduced from **27 kWh/m^2/year** to **20.54 kWh/m^2/year** by various energy-efficient techniques such as the use of solar PV panels, the application of biofuel, and smart materials, and maximum usage of natural ventilation and daylighting to eliminate the use of artificial solutions.

BASELINE EPI – 27 kWh/m^2/year
ACHIEVED EPI – 20.54 kWh/m^2/year

6.7.1 SOLAR PV PANELS

Solar power is the most common type of renewable energy that is abundantly available in the region. Most energy-efficient buildings use solar PV panels to generate their renewable energy. It is because this energy is available in surplus amounts throughout the year and maintenance and construction cost is very low in comparison to other RE systems.

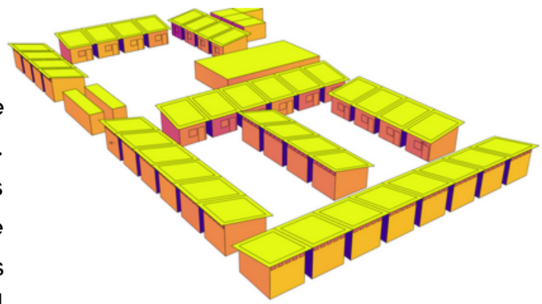


Fig no. 47 Solar Potential through simulations

The total energy consumption of the project is **64,701 kWh per year** and the total energy generation through solar power is **89,060 kWh per year** over an area of **195.2m^2** distributed to **42 housing modules.** Therefore, after deducting the consumed amount of energy, the total energy left is **24,359 kWh per year**, thus achieving a positive level of energy efficiency.

6.7.2 BIO GAS FUEL

Biogas is an environmental-friendly, renewable energy source that caters to the self-sufficiency of the entire project. It is produced when organic matter from the site, such as human waste goes under anaerobic digestion to produce fuel on site that can be used for all kitchen purposes including cooking and heating, reducing the need for external services and fuels.
The total amount of waste generation is **102 kg per day** which sources **504.02 MJ of energy** in the form of natural gas used for cooking.

6.7.3 SMART MATERIALS

The use of low carbon emitting and high thermally insulating construction materials such as rockwool, smart low emittance glass for window coverings that block high solar radiation in summers and regain it in winters, etc. reduce the energy consumption to a great degree while lowering overall costs and emissions.
Creating wall panel help us to achieve energy efficient modules for the construction workers.

6.7.4 EPI CALCULATIONS

The Energy Performance index(EPI) was brought to **20.54 kwh/sq.m.** from **27 kwh/sq.m.** This value is achieved by including the power losses and safety factor of 1.5. If we remove this criteria then we have achieved the EPI value of 12.79 kwh/sq.m. successfully. The calculation of EPI is given in the below table:

Sr.no.	Function	Area in Sq.m. (per unit)	Appliances	Wattage	Average Working hours (anually)	Total Energy Consumption (kwh)
	Living Zone					
1	Sleeping units					
	Family Unit	20	2 LED Lights	2 x 14 ≈ 30	6 x 365 = 2190	1320
			2 Fan	2 x 70 = 140	10 x 365 = 3650	10220
			4 Socket	4 x 3 = 12	4 x 365 = 1460	17.52
	Bachelors Unit	20	2 LED Lights	2 x 14 ≈ 30	6 x 365 = 2190	1320
			2 Fan	2 x 70 = 140	10 x 365 = 3650	10220
			4 Socket	4 x 3 = 12	4 x 365 = 1460	17.52
	Bathrooms and washing area					
2	Bathroom units	1	1 LED Light	1 x 4 = 4	3 x 365 = 1095	43.8
			Geysers(3 units)	2 x 2000 = 4000	1 x 365 = 365	1460
	Toilet					
3	Toilet	1	1 LED Light	1 x 4 = 4	3 x 365 = 1095	43.8
	Common Zone					
4	Kitchen	50	4 Tube Light	4 x 18 = 72	6 x 365 = 2190	157.68
			3 Exhaust Fan	3 x 32 = 96	6 x 365 = 2190	210.24
			1 Mini Fridge	1 x 300 = 300	10 x 365 = 3650	1095
5	Dining	130	10 Tube Light	10 x 18 = 180	3 x 365 = 1095	197.1
			10 Fan	10 x 70 = 700	3 x 365 = 1095	766.5
			Water Purifier	2 x 300 = 600	8 x 365 = 2920	1752
6	Washing Area		1 LED Light	1 x 4 = 4	1 x 365 = 365	1460
	Well - being Zone					
7	Medical Room	20	2 LED Lights	2 x 14 = 30	6 x 365 = 2190	65.7
			2 Fan	2 x 70 = 140	10 x 365 = 3650	511
	Services					
8	Storage	20	2 LED Lights	2 x 14 = 30	4 x 365 = 1460	65.7
9	Electric Service Room	20	2 LED Lights	2 x 14 = 30	2 x 365 = 730	21.9
10	Pumps			2 x 750 = 1500	1 x 365 = 365	547.5
	Working Areas					
11	Office	20	2 LED Tube Light	2 x 18 = 36	7 x 365 = 2555	91.98
			2 Fan	2 x 70 = 140	10 x 365 = 3650	10220
	Circulation					
11	Toilet Passage		4 LED Lights	4 x 14 = 56	5 x 365 = 1825	102.2
12	Dwelling unit passage		30 LED lights	30 x 14 = 420	5 x 365 = 1825	766.5
13	Green Space		18 LED lights	18 x 14 = 252	5 x 365 = 1825	459.9
					Total	43153.54
						EPI = (43150 x 1.5)/3150 = 20.54 kwh/sq.m.

Table No. 1 EPI Calculations

20.54	23%	27
Site EUI kWh/sq.m.	Saved vs. Baseline	Baseline EUI kWh/sq.m.

Fig no. 48 Simulated Energy Performance Index (EPI)

Energy Used per Month

The simulation is done on Climate Studio with the input parameters given above. The final EPI comes out to be **20.54 Site EPI kWh/m^2/year**. The energy is majorly used in equipment and lights as shown above.

Natural ventilation, low thermal mass gain, Maximizing Natural lighting, use of climate responsive strategies and low glare are all passive techniques that help the units run more efficiently in terms of energy use. The case study **GREEN TRANSIT SHELTER** came to the conclusion that EPI of **18-25 kWh/m^2/year** was appropriate, even if the intended target EPI was **20-22 kWh/m^2/year**.

Appliances	Watt	Cost	Description
LED Light Bulb	4	₹ 120.00	PHILIPS 4W B22 LED Cool Day Light Bulb, Pack of 2 (Ace Saver)
LED Light Bulb	14	₹ 300.00	PHILIPS 14W E27 LED Crystal White LED Bulb
LED Tube Light	18	₹ 450.00	PHILIPS Ujjwal Bright 18-Watt LED Batten Tubelight (Cool Day Light)
Fan	70	₹ 2,174.00	1050 mm FAN AEROKING BROWN - SKU: FHCAKSTBRN42 - 1050 mm Brown
Exhaust Fan	32	₹ 1,700.00	Havells Ventil Air DSP 300mm Exhaust Fan (Choco Brown) (FHVVEMTBRN12)
Geyser	2000	₹ 5,300.00	Bajaj New Shakti Neo 15L Vertical Storage Water Heater Geyser 4 Star BEE Rated
Mini Fridge	300	₹ 18,000.00	Croma
Water Cooler	300	₹ 80,000.00	Blue Star

Fig no. 49 Technical Specifications Of Equipment's

People - Occupancy - 4
Area - 20 m^2
People Density - 0.2 P/m^2
Metabolic Rate - 0.8 met
Air Speed - 1 m/s

Lightning - Two LED's 14 W each
Lightning Power Density - 1.5 W/m^2
Target Illuminance - 150 lux (refer NBC 2016)

Equipment - Charging Point
Equipment Power Density - 3 W/m^2
Mechanical Ventilation
L/s/p - 2.5
L/s/m^2 - 0.3

6.8 WATER PERFORMANCE

For obtaining a net-zero water usage, we have used the rainwater harvesting technique along with low-flow fixtures having high efficiency and less wastage of water. Along with that, the per capita daily water consumption is also reduced to 95 liters.

	Per Capita daily consumption (l)	Number of occupants	Total daily consumption (l)	Grey-water filter efficiency
Baseline Case	135	170	22950	30%
Designed Case	95	170	16150	75%

Table no. 2 Total daily water consumption

Grey water is being recycled and reused with an efficiency of 75% i.e. of the total greywater generated, 75% would be reused.

The systems which are taken into account for achieving net-zero water usage are:

- Rainwater Harvesting System
- Root Zone System
- UDDT
- Low - flow, high-efficiency fixtures

Occupant's Activity	Percent usage	Quantity (lpd)	Grey water (%)	Black water (%)
Bathing	29.0%	4683.5	100%	0%
Washing	19.6%	3165.4	100%	0%
Drinking	4%	629.85	0%	100%
Cooking	3%	468.35	0%	100%
Toilet	17.0%	2745.5	0%	100%
Cleaning house	8.0%	1292	100%	0%
Washing Utensils	16.4%	2648.6	100%	0%
Others	3.20%	516.8	50%	50%

Table no. 3 Daily activities water distribution

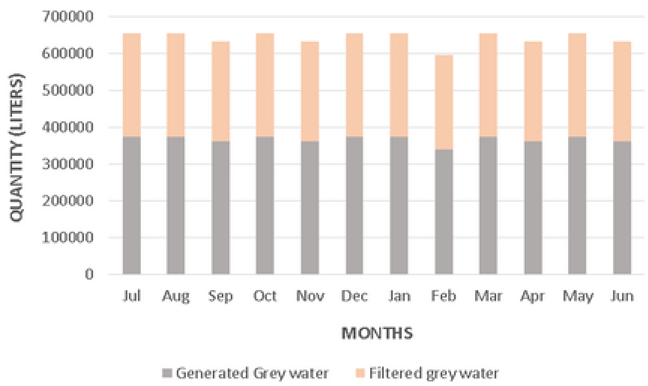


Fig no. 50 Recycled grey water graph

The greywater generated = 11897.9 lpd

= 11.8979 cu.m

Recycled Greywater = 0.75 X 11.8979 cu.m

= **8.923425 cu.m**

The capacity of the tank = 9 cu.m (approx.)

Assuming the height of the tank = 1.5m

Therefore, area of tank = 6m^2

Length (l) of tank = 3m

Breadth of tank = 2m

Hence, providing an underground greywatertank of size **3m X 2m X 1.5m**

Month	Days in month	Generated black water (liters)	Generated Grey water (liters)	Filtered grey water (liters)	Occupant demand (liters)
Jul	31	127165.1	373484.9	280113.675	500650
Aug	31	127165.1	373484.9	280113.675	500650
Sep	30	123063	361437	271077.75	484500
Oct	31	127165.1	373484.9	280113.675	500650
Nov	30	123063	361437	271077.75	484500
Dec	31	127165.1	373484.9	280113.675	500650
Jan	31	127165.1	373484.9	280113.675	500650
Feb	28	115884.325	340353.175	255264.8813	456237.5
Mar	31	127165.1	373484.9	280113.675	500650
Apr	30	123063	361437	271077.75	484500
May	31	127165.1	373484.9	280113.675	500650
Jun	30	123063	361437	271077.75	484500

Table no. 4 Occupants monthly water demand

Average water demand per day = 500650/31 liters = 16150 liters
Requirement of water from source = 16150 - 11897.9 = 4252.1 liters
Capacity of Storage tank = 4.2521 cu.m = 5 cu.m (approx.)
Assuming height of tank = 1.5m. Therefore, area of tank = 3.333 m = 4 m (approx.)
length (l) = breadth (b) = 2m X 2m
Hence, providing a storage tank of size **2m X 2m X 1.5m**

6.8.1 RAINWATER HARVESTING

Rainwater harvesting surfaces	Area (sq.m)	Runoff coefficient	Effective catchment area (sq.m)
Roof Surfaces	1180	0.85	1003
Hardscape areas	1584	0.7	1108.8
Softscape areas	336	0.3	100.8
Total Effective catchment area			2212.6

Table no.4 Rainwater catchment area

Months	Rainfall (mm)	Effective Rain (mm)	Harvested rainwater (l)
July	345.44	340	753258
August	342.9	338	747638
September	154.94	150	331757
October	35.56	31	67617
November	10.16	5	11417
December	7.62	3	5797
January	12.7	8	17037
February	10.16	5	11417
March	7.62	3	5797
April	5.08	0	177
May	17.78	13	28277
June	147.32	142	314897
Total Runoff in Litres			2295086

Table no. 6 Monthly rainwater collection

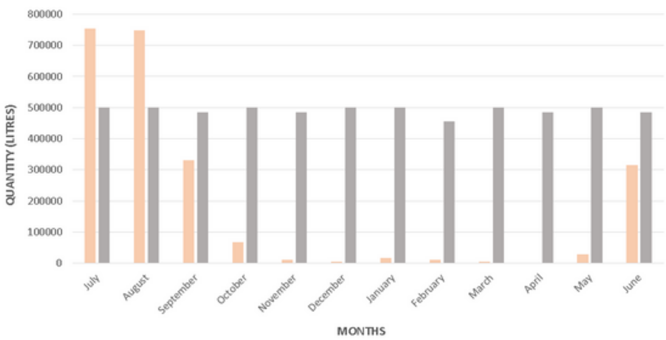


Fig no. 51 Rainwater harvesting

Highest monthly water harvested = 753258 liters
= **753.258 cu.m**
Per day rainwater harvested = 753.258/31 cu.m
= **24.29 cu.m**
Capacity of Rainwater tank = **25 cu.m** (approx.)
Assuming height of tank = **1.5m**
Therefore, area of tank = 25/1.5 m^2 = 16.66 m^2
Length (l) of tank = 4.5m
Breadth of tank = 4m
Hence, providing rainwater tank having a size of 4.5m X 4m X 1.5m.
Dividing the area of tank into two parts since locating at two different places.
Hence, Size of one tank = 3m X 2m X 1.5m

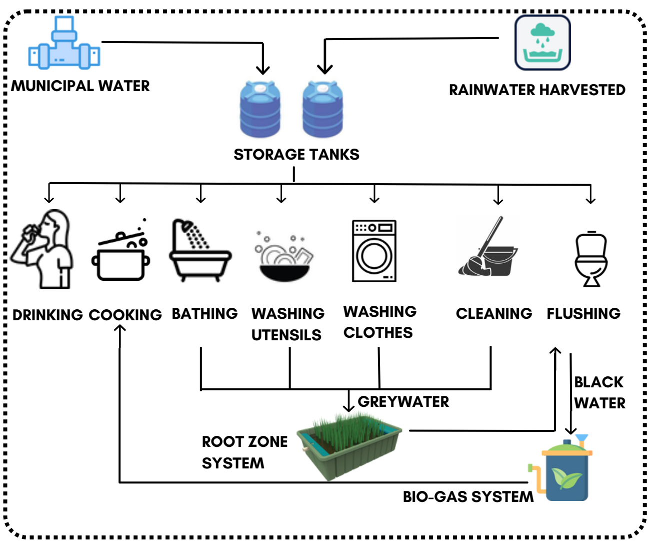
6.8.2 FIXTURE DETAILS

Keeping in mind the wastage of water through fixtures, we have chosen to use the fixtures that have high efficiency and less water wastage. The different fixtures to be installed are:

Fixture	Water Discharge	Efficiency	Cost (₹)
Aerator	3lpm and 4lpm	70-80%	89.00
3/6 Dual Flush Toilet	3lpf and 6lpf	60-70%	750.00
Showerhead	8lpm max.	60%	500.0 0

Table no.7 fixture comparison

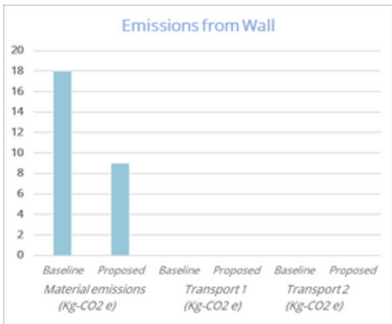
6.8.3 WATER CYCLE

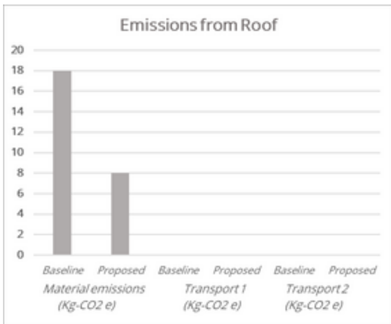


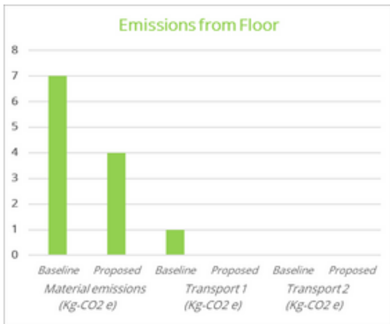
6.9 EMBODIED CARBON

The embodied carbon is based on the planning of building materials and construction technologies that reduce greenhouse gas emissions, which is required for net-zero global emissions. Through our design, we tried to reduce more and more embodied carbon from the building materials. We selected the **building material with lower GWP (Global Warming Potential)** without affecting the strength, fire resistance, durability, thermal resistance, and cost of the material. The material selection and availability of materials in the proximity of the site were the two main factors that contributed to achieving the system of low embodied carbon.

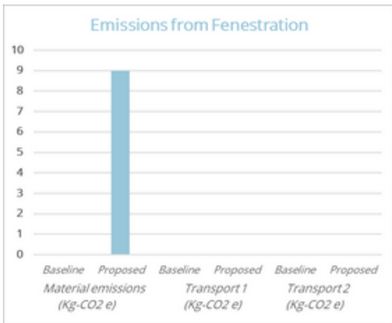
6.9.1 CARBON EMISSIONS FROM DIFFERENT SYSTEMS







Proposed Materials	GWP (in kg)
Rockwool	1
Bamboo mat Corrugated Sheet	0.5
Bamboo	0.2
Low Emitence Glass Fiber	1.7
Gypsum Panel	0.26
Fiber Cement board	0.41



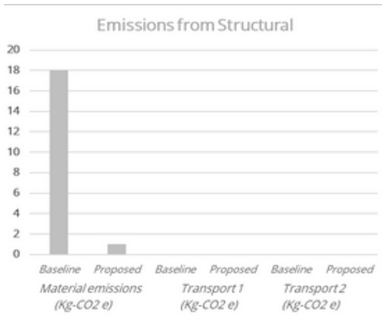


Fig no. 52 Carbon emission from different systems

6.9.2 BASELINE AND PROPOSED SYSTEM

After the selection of material, we compared the systems used in the baseline design with that in the proposed design. The comparison included emissions from wall, roof, floor, fenestration, and structure the grand total emissions per functional unit in the **baseline design** is **62 Kg-CO2e,** and in the **proposed design** is **31 Kg-CO2e.**

Thus, we are successful in reducing carbon emissions by 50% in the proposed design with respect to the baseline design.

System Type	Baseline				Proposed			
	Material emissions	Transport 1 (Kg-CO2 e)	Transport 2 (Kg-CO2 e)	Total (Kg-CO2 e)	Material emissions	Transport 1 (Kg-CO2 e)	Transport 2 (Kg-CO2 e)	Total (Kg-CO2 e)
Wall	18	0	0	18	9	0	0	9
Roof	18	0	0	18	8	0	0	8
Floor	7	1	0	8	4	0	0	4
Fenestration	0	0	0	0	9	0	0	9
Structural	18	0	0	18	1	0	0	1
	Grand Total emissions per functional unit (Kg-CO2 e)			62	Grand Total emissions per functional unit (Kg-CO2 e)			31

Table no.8 Embodied Carbon Calculation

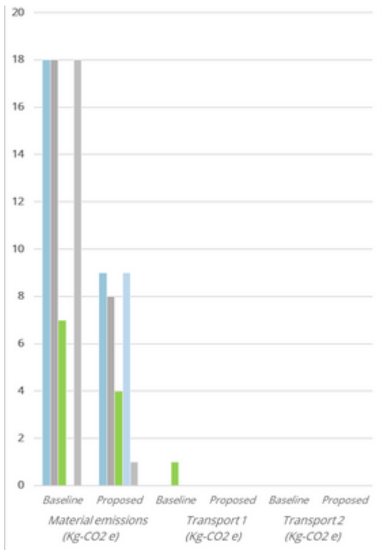


Fig no.53 Summary of emission per functional unit

7. VALUE PROPOSITION

Construction worker housing is a type of accommodation specifically designed and built for workers in the construction industry.

Our housing solution is a game changer for construction workers.
You'll save money, limit carbon emissions, feel safer and more secure, and live in a home that fits your needs.

Its value proposition lies in several key benefits:

- **Easy to assemble** - Our modular housing units are designed with safety and security in mind—and they're not just good for your construction workers.
- **Adaptable to different weather conditions** - Housing can be built with materials that are durable, waterproof, and fire-resistant. It's also easy to repair, which makes it an ideal choice for construction workers who work in harsh environments.
- **Affordable** - The construction industry is one of the most energy-intensive in the world, and it's no surprise that a lot of companies have taken steps to reduce their carbon footprint. But what about housing? You might not think about it, but buildings tend to be quite expensive—and a lot of people could benefit from having access to affordable housing. That's why we've developed Econique. Our technology allows buildings to be built with zero carbon emissions.
- **Cost savings:** Modules are typically more affordable than traditional housing options in the area, which helps workers/Contractors save money on rent and other living expenses.
- **Proximity to job sites:** These housing units are often located near the construction site, saving workers time and money on transportation.
- **Comfortable living conditions:** Many construction worker housing units are designed to be comfortable and provide basic amenities like Ventilation, heating, and Human Comfort, which can improve the living conditions for workers.
- **Increased productivity:** By providing workers with comfortable living conditions and easy access to job sites, construction worker housing can help improve worker productivity and reduce downtime.
- **Safety and security:** These housing units are typically designed to be safe and secure, providing a sense of security for workers and reducing the risk of accidents or other incidents.

Overall, construction worker housing provides a practical solution for workers in the construction industry who need affordable, convenient, and comfortable living arrangements while working on job sites. It can help improve the quality of life for these workers and ultimately lead to a more productive and efficient construction industry.

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APPENDIX

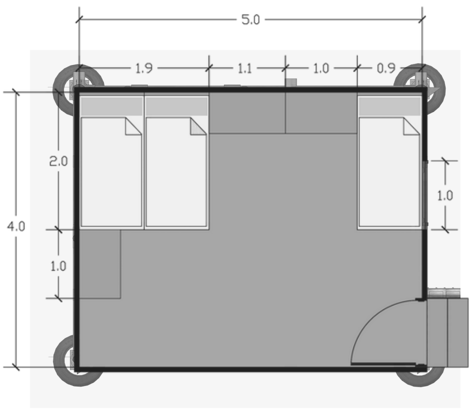
BUILDING AREA PROGRAMME

AREAS	AREA PER UNIT IN m²	NO OF OCCUPANTS	NO. OF UNITS	AREA IN m²
BACHELOR'S UNIT	20	4	30	600
FAMILY'S UNIT	20	3	12	240
BATHROOM	1	1	10	10
TOILET	1	1	10	10
KITCHEN	50	-	1	50
DINING	130	50	1	130
SERVICES				
MEDICAL ROOM	20	-	1	20
CREACHE	20	10	1	20
OFFICE	20	2	1	20
ELECTRIC SERVICE ROOM	20	-	1	20
STORAGE ROOM	20	-	1	20
TOTAL BUILT UP	-	-	-	1110

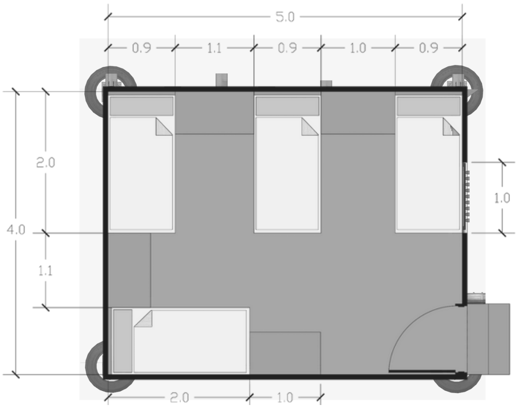
ARCHITECTURAL DRAWINGS

SITE PLAN

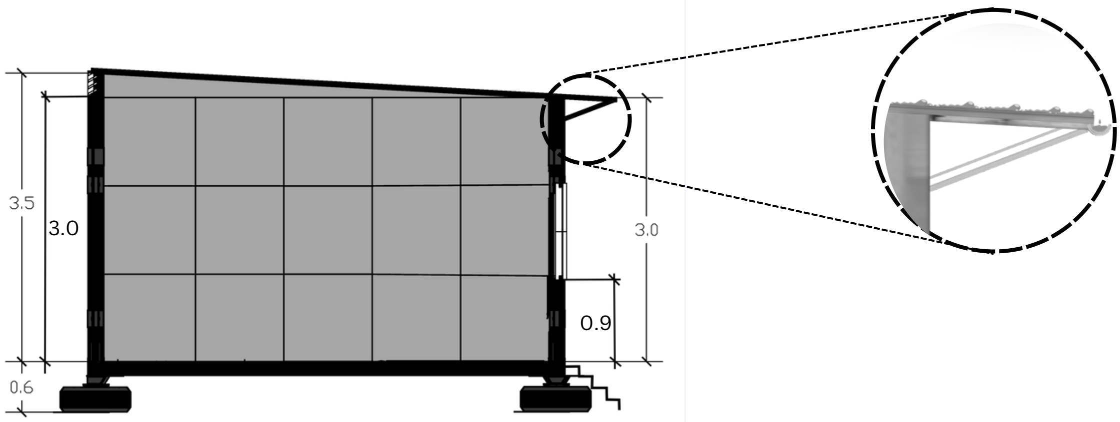
1. FAMILY UNITS
2. BACHELOR UNITS
3. ELECTRIC SERVICE ROOM
4. STORAGE
5. OFFICE
6. MEDICAL ROOM
7. DINING HALL
8. KITCHEN
9. RAINWATER TANKS
10. WATER STORAGE TANK
11. WASHROOMS
12. ROOT ZONE PLANTATION
13. GREEN SPACES



FAMILY UNIT PLAN

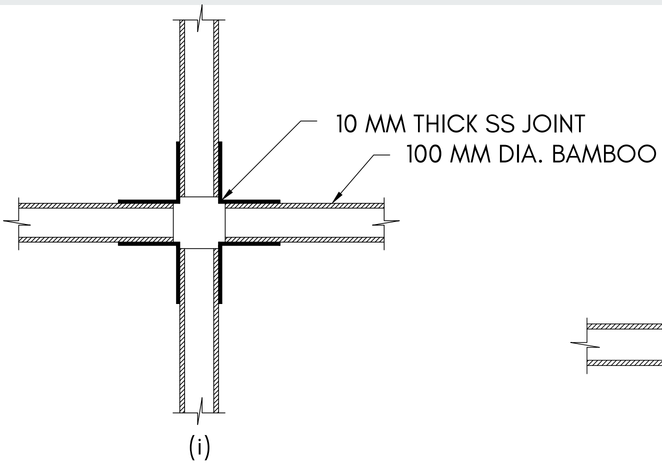


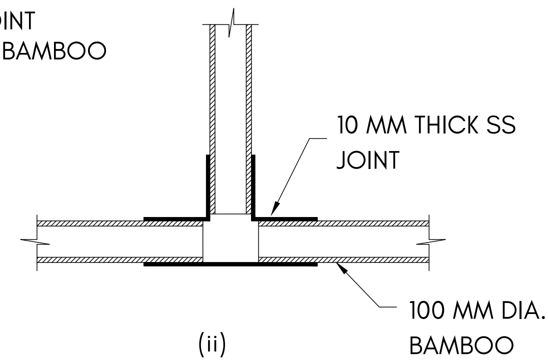
BACHELOR UNIT PLAN

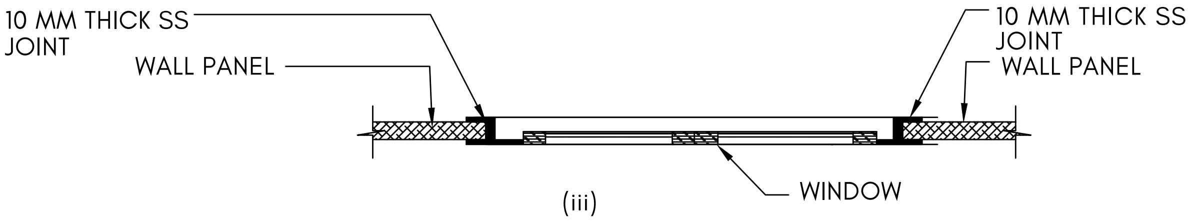


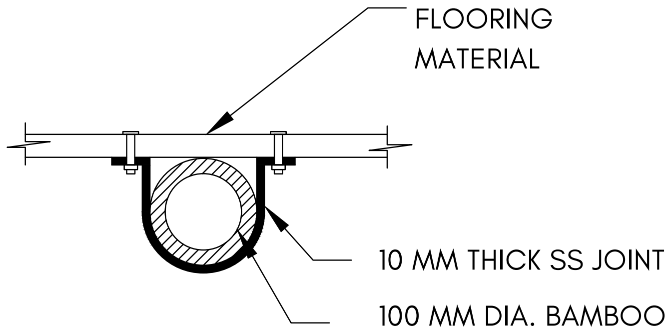
UNIT SECTION

JOINERY DETAILS









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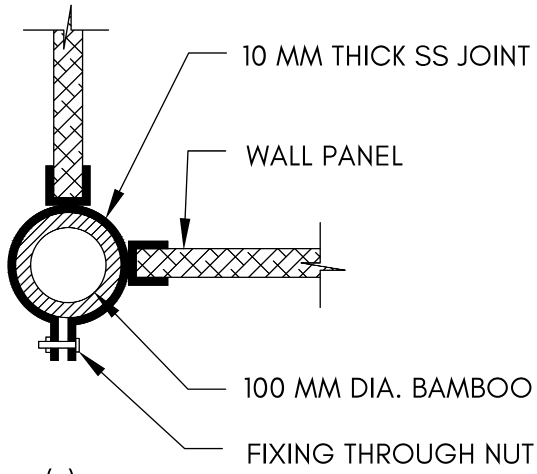

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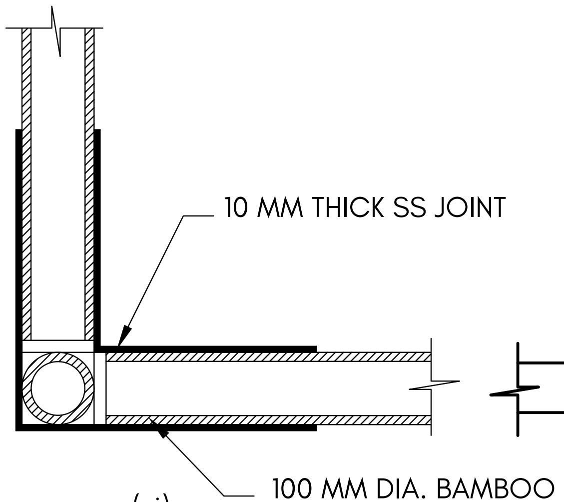

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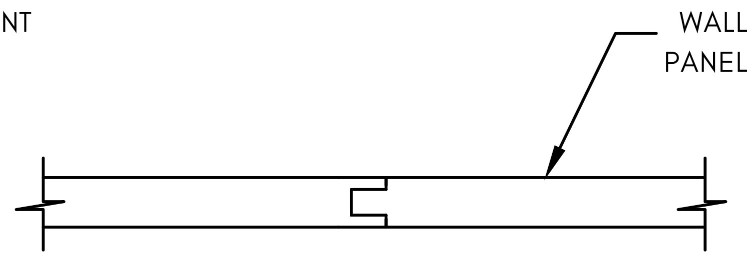

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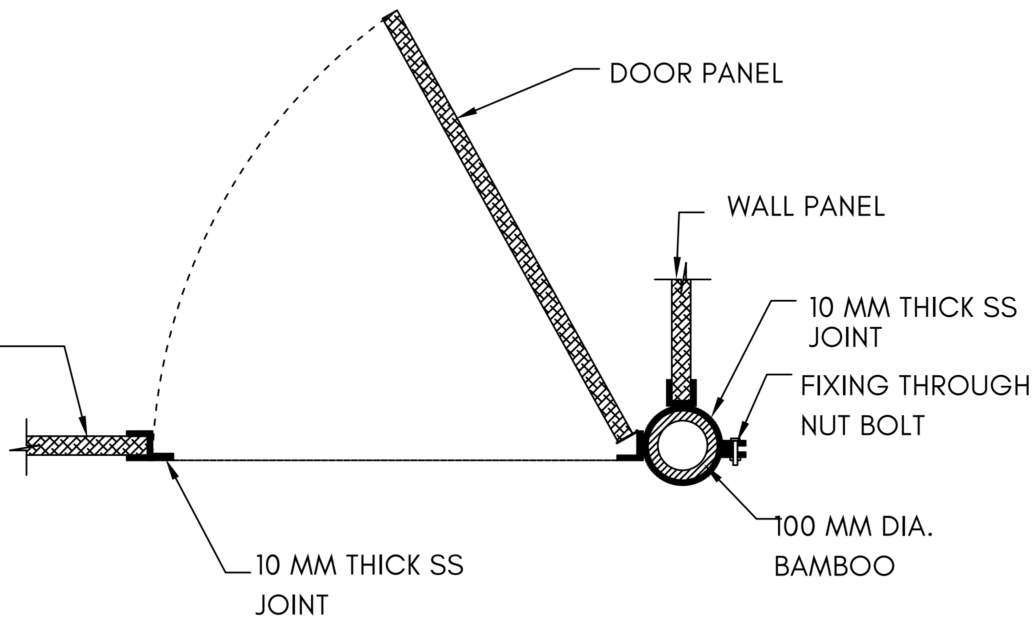


(viii)

CONSTRUCTION COST SUMMARY

No.	Item Description	Proposed Design Estimate				
		Quantity	Rate	Amount (Million INR)	Cost per sqm (INR)	Notes Required
A. CIVIL WORKS						
1	STRUCTURAL WORK					
1.1	Steel Joints	840	400	0.3	285	YES
1.2	Bamboo	3,360	33	0.1	95	YES
1.3	Iron column	-	-	-	-	
	"Insert Row" above this row to add more items					
2	MODULE WORK					
2.1	Gypsum board along with rockwool	2,142	356	0.8	646	YES
2.2	Bamboo corrugated sheets	1,008	340	0.3	290	YES
2.3	Tin sheets	-	-	-	-	
	"Insert Row" above this row to add more items					
	SUB- TOTAL (A)			1.6	1,316	
B. INTERNAL WORKS						
3	FLOORING WORK					
3.1	Flooring- Unit	840	700	0.6	498	YES
3.2	Cemented flooring	-	-			
	"Insert Row" above this row to add more items					
4	DOORS					
4.1	Number of Unit door and window	94	4,700	0.4	374	YES
	"Insert Row" above this row to add more items					
	SUB-TOTAL (B)			1.0	873	

C. MEP SERVICES						
5	ELECTRICAL & ALLIED SERVICES					
5.1	Number of Light Fittings		94	150	0.0	12
5.2	Number of Fan		47	1,200	0.1	48
6	PLUMBING & SANITATION					
6.1	Fixtures and Fittings	BUA Sqm	20	400	0.0	7
6.2	External Drainage	BUA Sqm	440	100	0.0	37
6.3	Rainwater Storage system	BUA Sqm	2	3,336	0.0	6
6.4	Portable washroom		20	25,000	0.5	424
7	FIRE FIGHTING					
7.1	Fire Extinguishers & Buckets	BUA Sqm	20	6,500	0.1	110
8	IBMS AND SECURITY SYSTEM					
8.1	Fire Alarm System	BUA Sqm	20	2,000	0.0	34
	SUB-TOTAL (C)				0.8	677
D. EQUIPMENT & FURNISHING						
9	Unit Interiors:					
9.1	Number of Iron shelves		-	-	-	-
9.2	Number of wrought iron bed		-	-	-	-
9.3	Number of Wooden Bed		156	6,400	1.0	846
9.4	Number of wardrobe		156	4,000	0.6	529
	SUB-TOTAL (D)				1.6	1,375
E. LANDSCAPE & SITE DEVELOPMENT						
10	LANDSCAPING					
10.1	Landscaping and Hardscape	Sq.m	-		-	-
	SUB-TOTAL (E)				-	-
	CONTINGENCY (E)		5%		0.3	212
	TOTAL				5.3	4,453

ENERGY PERFORMANCE

Appliances	Watt	Cost	Description
LED Light Bulb	4	₹ 120.00	PHILIPS 4W B22 LED Cool Day Light Bulb, Pack of 2 (Ace Saver)
LED Light Bulb	14	₹ 300.00	PHILIPS 14W E27 LED Crystal White LED Bulb
LED Tube Light	18	₹ 450.00	PHILIPS Ujjwal Bright 18-Watt LED Batten Tubelight (Cool Day Light)
Fan	70	₹ 2,174.00	1050 mm FAN AEROKING BROWN - SKU: FHCAKSTBRN42 - 1050 mm Brown
Exhaust Fan	32	₹ 1,700.00	Havells Ventil Air DSP 300mm Exhaust Fan (Choco Brown) (FHVVEMTBRN12)
Geyser	2000	₹ 5,300.00	Bajaj New Shakti Neo 15L Vertical Storage Water Heater Geyser 4 Star BEE Rated Heater For Water Heating with Titanium Armour Swirl Flow Technology Glasslined Tank White 1 Yr Warranty Wall Mounting

BIOGAS CALCULATIONS

- **Estimated volume of home biogas plant by height and diameter-**

- For diameter 1.2m and height of 2.0m
- Digester volume(cu.m)-1.1
- Gas storage volume(cu.m)-0.47
- Daily gas production(cu.m/day)-0.79

- Daily gas production-0.79cu.m/day
- No. of biogas plant-25
- Total daily gas production-19.75cu.m/day

- 1cu.m. of biogas-22MJ of energy
- 0.79cu.m. of biogas-17.38MJ of energy
- 19.75cu.m. of biogas-434.5MJ of energy

- Animal waste feedstock properties-
- Buffalo/cow-10-12kg per day
- Hens-7.5kg per day
- **Note**-majorly used animal waste stock is cow/buffalo and poetry farm stocks

- Cost of one plant-5000-7000RS.
- Total cost of project-125000RS.

SOLAR CALCULATION

ENERGY CALCULATIONS:

Note - Solar calculations are calculated using EPI (including safety factor and power losses. No. of solar panels can be reduced by excluding this safety factor and power losses.

- Achieved EPI-20.54 kwh/m^2/yr.
- The total area of site-3150m^2
- Total energy consumption of the whole site-64701 kWh/yr.
- Total power consumption of the whole site- 2695.8 kW/yr.
- Total energy consumption per day-177263.01 Wh.
- Total power consumption per day-7385.9 W.

SOLAR PANELS CALCULATIONS:

SOLAR PANELS-

- **Power required from PV (wh.)/Output power of solar panels (wh.)-** 30353.2/250=121.4
- 122 solar panels are required to complete the total energy consumption of the whole site.
- **NOTE- 250 w. PV panels are taken as standard solar panels.**
- Area for one panel-1.6m^2
- Total area required for 122 solar panels-195.2m^2
- Cost of one solar panel-7500RS.
- The total cost of solar panels-915000RS.

BATTERY-

- Total capacity(AH.)-5561.59AH.
- No. of batteries -28

INVERTER-

- Total capacity-3000w.

FINANCIAL SAVINGS-

- Monthly-10000RS.
- Annually-120000RS.
- Life-time(25 years)-3000000RS.

CARBON EMISSION-

- Carbon dioxide emission mitigated is-308 tonnes.
- This installation is equivalent to planting 492 Teak trees over the lifetime.

PRODUCT DETAILS-

- Brand-Luminous
- Material-Metal
- Item Dimensions (LxWxH)-167 x 101 x 5 Centimeters
- Efficiency-High Efficiency
- Maximum Voltage 24 Volts
- Maximum Power 270 Watts
- Item Weight- 1 kg

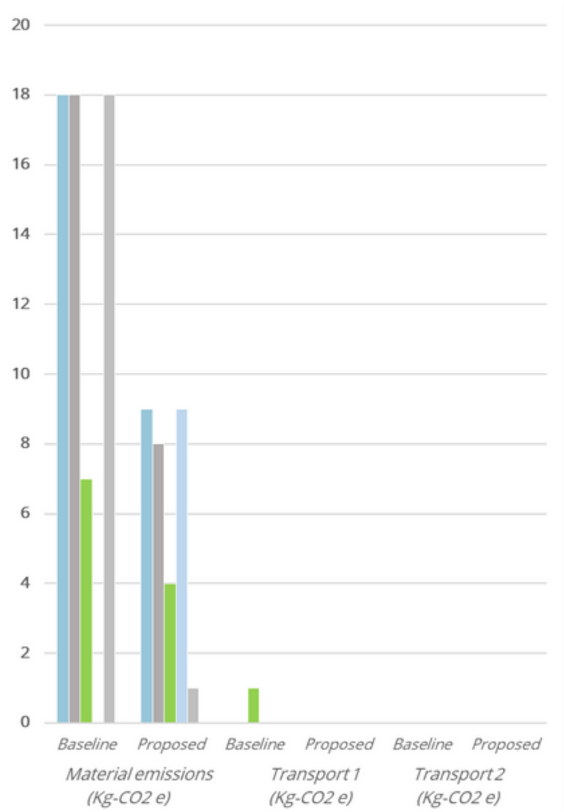
EMBODIED CARBON

We selected the **building material with lower GWP (Global Warming Potential)** without affecting the strength, fire resistance, durability, thermal resistance, and cost of the material. The material selection and availability of materials in the proximity of the site were the two main factors that contributed to achieving the system of low embodied carbon.

After the selection of material, we compared the systems used in the baseline design with that in the proposed design. The comparison included emissions from wall, roof, floor, fenestration, and structure the grand total emissions per functional unit in the **baseline design** is **62 Kg-CO2e,** and in the **proposed design** is **31 Kg-CO2e.**
Thus, we are successful in reducing carbon emissions by 50% in the proposed design with respect to the baseline design.

BASELINE AND PROPOSED SYSTEM

Proposed Materials	Unit	GWP
Rockwool	Kg	1
Bamboo mat Corrugated Sheet	Kg	0.5
Bamboo	Kg	0.2
Low Emitence Glass Fiber	Kg	1.7
Gypsum Panel	Kg	0.26
Fiber Cement board	Kg	0.41
Baseline Materials	**Unit**	**GWP**
Electrogalvanised Steel sheet	Kg	3
Steel Section	Kg	2.5
Steel window frame	Kg	3.5
Cement Mortar	Kg	0.14
Gypsum Panel	Kg	0.26



System Type	Baseline				Proposed			
	Material emissions	Transport 1 (Kg-CO2 e)	Transport 2 (Kg-CO2 e)	Total (Kg-CO2 e)	Material emissions	Transport 1 (Kg-CO2 e)	Transport 2 (Kg-CO2 e)	Total (Kg-CO2 e)
Wall	18	0	0	18	9	0	0	9
Roof	18	0	0	18	8	0	0	8
Floor	7	1	0	8	4	0	0	4
Fenestration	0	0	0	0	9	0	0	9
Structural	18	0	0	18	1	0	0	1
	Grand Total emissions per functional unit (Kg-CO2 e)			62	Grand Total emissions per functional unit (Kg-CO2 e)			31

BUILDING SYSTEM NARRATIVE

LIGHTING SYSTEM

The lighting demand for an individual unit is achieved through maximizing daylighting, but since there is no even dispersion of light across the module, CFLs are installed for proper illumination during the day and nighttime.

THERMAL COMFORT

The buildings heating and cooling system consists of a combination of mechanical and natural ventilation. Mechanical including a fan, while natural ventilation is incorporated by eco coolers, a terracotta jaali fixed to the wall opening and cooling the inside air through venturi effect.

AUTOMATED OPERATION

The eco cooler comes in the form of a panel, that can be attached and detached to the window opening. The outside diameter of the jaali has larger openings to catch more hot air, while the inside diameter is significantly smaller and compresses hot air into cool. This lowers the temperature by 4-6 degree Celsius. The panel can be replaced with conventional glass panel, in winters, to avoid unnecessary cooling.

WATER SUPPLY AND WASTE MANAGEMENT

Water is supplied throughout the site and modules by municipal connection while the greywater generated from cooking, bathing etc, is reused through root zone treatment plants for different purposes such as flushing. The rainwater is collected into tanks for the users on site to facilitate daily activities. Urine diverting toilets are used as an alternative to pit latrines and work by separating urine and solids at source. Urine is collected at the front and piped through the toilet to the outlet. The solids fall into a container at the back of toilet.

SOLAR PANELS

Solar systems are made up of solar panels (modules), a mounting system, and a solar inverter with computerized controller. Solar panels produce DC electricity from sunlight. Then the inverter converts the generated electricity into AC, so that it can be used in the household. The computerized controller connected in the electric room on site, manages the solar system and ensures optimal performance. The total energy generation through solar power is 19,500 kwph per year over an area of $64m^2$ distributed to 42 housing modules.

INSPECTION AND MAINTAINENCE

It is important that the panels are clean and there is nothing blocking them from efficiently absorbing the sun. One should avoid spraying them with cold water while they are hot because that might damage them, and the system should be examined every 4-6 years by an installer.

BIO GAS PLANT

The energy demands of the module for cooking and heating are attained by the use of bio gas plant, a renewable alternative. The organic waste from the site is undergone different chemical processes, and is converted into fuel for the entire site.

AUTOMATED OPERATION

The on-site bio gas plant connects to the module kitchens through a pipeline that produces gas for cooking and heating, thereby avoiding the use of external services for energy

CONFIRMATION LETTER

Date 28/09/2022

To,

The Director,

Solar Decathlon India

Dear Sir,

This is to inform you that our organization Mr. Vinod Kumar Shukla Construction Infra Projects Ltd. has provided information about our Elevated Corridor, Bhopal project to the participating team led by Maulana Azad National Institute of Technology Bhopal , so that their team ECONIQUE 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 intend to have a representative from our organization attend the Design Challenge Finals event in April, if this team is selected for the finals.

We would like 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,

V K S C INFRA PROJECTS LTD.

28/09/2022

Name of Representative: Jai Prakash Sharma

Designation: Project Manager

Email: bhopalvksc1@gmail.com

Phone: 7000651214