Solar Decathlon India

COMMUNITY RESILIENCE SHELTER

Final Design Report
April 2023

MANIPAL SCHOOL OF ARCHITECTURE AND PLANNING
MANIPAL
(A constituent unit of MAHE, Manipal)

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
A Constituent Institution of Manipal University

रचना संसद

a|a MUMBAI

CONTENT

LIST OF TABLES

LIST OF FIGURES

REVIEWER'S RESPONSE

REVIEWER 1

SECTION	REVIEWER'S COMMENT	OUR RESPONSE
Energy performance	It is great to see that you have calculated the energy reduction after the application of each strategy	No comments
Water performance	Your water performance calculations are very well detailed. You should compare it against your base case design for percentage efficiency.	Comparison between base and proposed case and percentage efficiency has been done, refer to page no. 12
Embodied carbon	You should also consider emissions during construction in your overall embodied carbon of the project.	We have calculated carbon emissions during construction, refer page no. 13
Resilient design	You should specify the capacity of the battery or or generator for quantifying energy security and capacity of the water storage for quantifying water security.	Quantification of water and energy security has been done. Battery and water storage capacity has been mentioned, refer page no. 16
Engineering operation	You can further input structural and electrical drawings for reference.	Structural and Electrical drawings have been added to the Appendix. Refer to Appendix Fig C and Fig D respectively.
Architectural design	You should take into account the differently abled population and incorporate universal design strategies such as ramps and handicap toilets.	We have added ramps to access the exterior of the building to access the Multipurpose Hall. Refer page no. 20

REVIEWER 1

Affordability	Your cost estimate is reasonable. You should also consider operation and maintenance cost of the building for future calculations.	The required operation and maintenance cost has been looked into and added as LCC analysis, refer page no. 25
Innovation	Your multi-functional modular furniture system is interesting. You should also look into additional architectural and technological innovations.	We have included two additional innovations, refer pages 26 to 28
Health and wellbeing	You should also consider IAQ and IEQ optimum for the occupants.	We have looked into the parameters of IAQ and IEQ. Refer page no. 29
Value proposition	No comments	-

REVIEWER 2

SECTION	REVIEWER'S COMMENT	OUR RESPONSE
Energy performance	You have not undertaken reduction of loads demonstrated with annual energy analysis against the baseline scenario for each strategy separately, for passive design, building envelope, lighting and plug loads. Your EPI of 11 is quite achievable for a non-ac building. In fact you should calculate a lower EPI for Disaster Periods (switching off lights earlier, etc.) Still, you have net positive renewable electricity, which is good.	We have calculated the EUI reduction for each ECM separately against the baseline. Refer page no. 7 The Envelope U- values have been re-calculated. Please refer to Table No. 8 Outline Specifications 1 in the Appendix.
Water performance	Do increase to 100 at least (you have the area, you ought to add a floor, otherwise your 45 people are housed on the same floor, and women will feel shy going to the same toilet as the men.) Your UGT does not take all the annual rainfall. You are effectively storing the rain in the ground and then pumping it (albeit with free and renewable energy) for daily/weekly use. I don't know whether ground recharge is allowed by SDI rules, since storing almost 6 months of water would require a very heavy investment, reducing affordability.	A tank of 180 Cum of volume is given under the structure which can take all the annual rainfall and filtered grey water. Refer page no. 10
Embodied carbon	The idea of Agrocrete for wall infills is brilliant! However, you RC framed structure may have substantial amounts of steel in slabs, beams, and columns. But over the years (calculate how many) this can be mitigated by the surplus renewable energy produced.	The calculations showing the offset of carbon emissions by renewable energy can be referred on page no. 13
Resilient design	You have a flood proof and earthquake resistant and wind mitigation structure	No comments

REVIEWER 2

SECTION	REVIEWER'S COMMENT	OUR RESPONSE
Engineering operation	you have over claimed the U-value of a thin bamboo wall (1.538) instead of a half brick wall (U=1.63)! Bamboo can never be better than a brick wall, especially as there will be little gaps in the bamboo wall. You need only be better in external walls, not internal walls. Likewise, how do you reduce U-value of the roof slab from 4.873 to 4 when the material and thickness is the same	The U- values have been re-worked. The revised values can be found in appendix, table 8.Outline Specifications -1 The roof system specifications can be found in appendix in table 8.Outline Specifications -1
Architectural design	Do increase the number of people served to 100 at least. (you have the area, and you ought to add a floor, otherwise your 45 people are housed on the same floor, and women will feel shy going to the same toilet as the men.)	Our project partner has provided us with requirements and constraints for the project and one of them being the Humanitarian standards and the height restrictions. Refer page No. 5 We are proposing our shelter as a prototype that can be replicated in the region to cater to a larger population. Hence, our project is restricted to an occupancy of 45 people. Refer page No. 1
Affordability	You will not be able to bring down your promoters' estimate from 700 Rs/sft to 600 Rs/sft! How can plumbing and electricity cost 3/4ths of baseline	The required changes have been made. Refer page no. 24 Plumbing and electricity breakdown has also been considered.
Innovation	The furniture is innovative, but are the bamboo poles on the top Won't it be difficult to sleep on them	A jute mattress has been provided on top of the bamboo poles for people to sleep on comfortably.
Health and wellbeing	No comments	No comments
Value proposition	No comments	No comments

EXECUTIVE SUMMARY

Headline: "AT LEAST 72 PEOPLE DEAD, hundred upon thousands of people lost their livelihood, as cyclone Amphan tears into Sundarbans and west Bengal", a quote from 2020 giving a glimpse into the trauma people undergo during un-anticipated disasters. Not only in India but all around the world, disasters wreak havoc. Take the recent earthquakes in Syria and Turkey as examples too.

Team Tattva, representing the Manipal School of Architecture and Planning in the Solar Decathlon Competition India, has taken up the challenge to create a space for the people in the cyclone-prone areas of the Sundarbans.

Tattva represents the four key elements of nature: fire, water, air, and earth, forming the basic fabric of the ecosystem necessary for survival. Our goal is to provide a haven for people during disastrous times. Giving birth to Trana. This translates to 'relief' in Sanskrit which reassures a space for people to come to when in need, that is, to shelter from "fire/water/air/earth".

Our project focuses on providing a net-zero energy disaster resilience shelter that is self-sufficient throughout the year.

The proposed site in Gopal Nagar, West Bengal, is a **cyclone-prone zone** with historical **wind speeds up to a maximum of 200 kmph** and falls under a **Zone IV earthquake-prone area**, according to the Indian geological surveys. We first assessed the foundation of our structure after thoroughly researching the land and its surroundings.

We considered **45 people** taking into account our Project partner's requirements in terms of structure and context. Thus we came up with a simple design that can hold the desired number of users, 45, with space for an additional 35 users if necessary. **The design also serves as a prototype** that can be replicated in the region to cater to a larger population. This design makes sure that **professional or experienced personnel are not required** in the construction process and can be customized or duplicated for a specific site in the wetland and marsh region.

Due to the need for more availability of standard data for the base case, a base model has been prepared to provide for comparison with an efficient structure. This strategy helped our team to compare various standards pertaining to the competition guidelines.

We started looking into structure form options and ran them through energy simulations to help understand the day lighting, heat gain, efficiency, etc., for the next phase of designing. Innovative ideas to attack the area limitation were thought of in terms of furniture and multi-functional spaces. With careful considerations of context and availability, construction materials were chosen, i.e. bamboo. Using the flooding to our advantage, we looked into systems that could **reuse the water coming onto the site**: giving us our **root zone filtration system and rainwater harvesting system**, and using treated grey water for flushing and irrigation. Using **low-flow fixtures** has allowed us to achieve a decrease from **135lcpd to 75lcpd**. And to make our structure, cost-efficient strategies such as the use of **local materials has cut costs by 0.9 Million INR**, **solar power energy generation with 5kW capacity**, out of which surplus which can be stored for disaster times helps bring down lighting costs, using **clerestory in large spaces reduce the LPD** requirements to **1.4 W/m2** and finally the **Life Cycle Cost of the structure for 25 years can be reduced by 1.91 Million INR.**

To conclude, using the above strategies, we have managed to **reduce our EUI from 66.08 to 11.83 kWh/m2/yr (82.1%)**, which has helped us attain a design of a protective space for vulnerable people from the surrounding area during disastrous hours and to also pose as a mandi and a weaving center to create jobs for the people during non-disastrous hours.

TEAM INTRODUCTION

Team Name: TATTVA

Division: Community Resilience Shelter

Institution Names :
1. Manipal School of Architecture and Planning (MSAP)
2. Rachna Sansad Academy of Architecture
3. Manipal Institute of Technology (MIT),

Team Members:

Paranjay Bhawsinghka (Team Lead) | B.Arch
Embodied Carbon

Raksha R Shetty | M.Des (Sustainable Design)
Energy Performance

Dikshitha Kylasa | M.Des (Sustainable Design)
Energy Performance

Sonali D Kamath | M.Des (Sustainable Design)
Design

Prisha Mahesh | B.Arch
Design

Aaron Lisboa | B.Arch
Innovation

Simran Khaitan | B.Arch
Innovation

Bhargav Santosh P | B.Arch
Water performance

Tejas Vikram | B.Arch
Health & Well being

Moksh Parmar | B.Arch
Resilience

Ujjwal Sharma | B.Tech (Civil)
Engineering & Operations

Nikita Patil | B.Arch
Affordability

Johann Paulose George | B.Tech (Civil)
Graphics

Suhani Khandelwal | B.Arch
Graphics

Background of the Lead Institution:
The Manipal School of Architecture and Planning (MSAP), Manipal was established in 1978. It strives to establish academic and professional excellence in architecture and design with state-of-the-art facilities.

Degree Programs :
Undergrad Programs-B.Arch, B.Des(FD), B.Des(ID)
Postgrad Programs-M.Des(ID), M.Des(FD), M.Arch(UDD), M.Des (SD)

Fig 2.1 Manipal School of Architecture and Planning

Garima Singh (Faculty Lead) | B.Arch., M.Arch
Asst. Professor, Senior scale, MSAP,MAHE

Dr. Nandineni Rama Devi | B.Arch.,M.Arch,Ph.d
Director, Professor | MSAP, MAHE

Amarnath Sharma |B.Arch., M.Arch
(Urban Design)

Anupama Pavithran | B.Arch, MBA(HR), M.Sc in PD, Asst. Professor, MSAP, MAHE

Vaibhav Jain | B.Arch., M.S
Asst. Professor-Senior scale MSAP, MAHE

Rutuja Sunil Ulhe | B.Arch., M.Arch
Asst. Professor, MSAP, MAHE

Ipsitaa Priyadarsini Das | B.Arch., M.Arch
Asst. Professor-Senior scale MSAP, MAHE

INDUSTRY PARTNER

GreenJams

GreenJams have provided us with a Carbon -ve material which is a patented vegetal concrete called Agrocrete. It comprises of discarded plant matter that would otherwise be burnt. To compare embodied carbon of hollow blocks is -0.15 kg CO_2 /kg.

DESIGN MANAGEMENT PROCESS

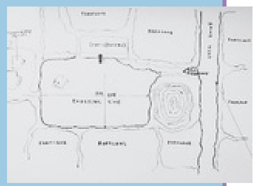
SDI REGISTRATION

WEEK 1
TEAM FORMATION

WEEK 4
CONFIRMING SEEDS INDIA AS OUR PROJECT PARTNER

SEEDS

PROJECT DETAILS GIVEN BY SEEDS

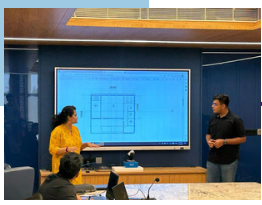


WEEK 5

WEEK 6
Division into 4 broader groups and preliminary research

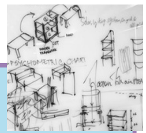
WEEK 7
Division into 10 contests and Starting Self Learning Modues

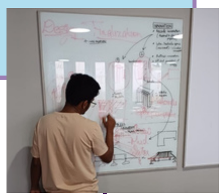
Completion of SLMs and finalization of design options through review meetings



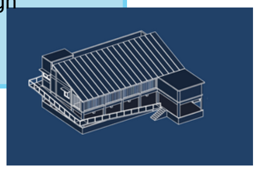
WEEK 9
SUBMITTED DELIVERABLE 2 AND BRAINSTORMING FOR DELIVERABLE 2

WEEK 11-18
Reflecting on Reviewers comments and coming up with strategies for final design

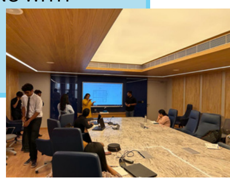




WEEK 19
Analyzing Final form and finalizing design



WEEK 26
REVIEW MEETING WITH FACULTY HEAD

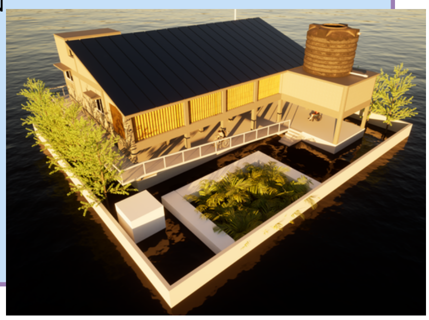


WEEK 27
Partnering with Green jams

GreenJams

WEEK 30
Addressing Reviewers comments after submission of D3

WEEK 35
SUBMISSION



TOOLS USED

REVIT, GRASSHOPPER, SKETCHUP, RHINOCEROS, CLIMATE CONSULTANT, STAAD PRO, CLIMATE STUDIO

AUTOCAD, PHOTOSHOP, POWERPOINT, EXCEL, DESIGN BUILDER, TWINMOTION, CANVA PRO

PROJECT BACKGROUND

Project Name : Trāṇa

Project Partner :

SEEDS (Sustainable Environment and Ecological Development Society) is a non-profit organization that enables community resilience. Since 1994, the organization has worked extensively on every major disaster in the Indian subcontinent. It has reached out to families affected by disasters and climate stresses, strengthened and rebuilt schools, homes and has invariably put its faith in skill-building, planning, and communications.

SEEDS Team Members

Shafat Mir
Lead Construction Management

Sumeet Agarwal
Senior Director – Project Management and Control

Ar. Arkadeep Roy
Architect – Sustainability

Ar.Shruti Nikhar
Senior Architect – Sustainability

Project Brief

The project is a community relief shelter that provides a safe space for vulnerable residents in the surrounding areas, sheltering them when disasters strike. The structure will function as the proposed shelter during disaster hours and as a mandi and weaving center, creating a space that helps generate income for the people thus helping eradicate unemployment caused due to disaster, during non-disaster hours.

Site context

Fig 3.1 Site Context

Location: Gopal Nagar Village, West Bengal, India, 743347

Climate: Warm & Humid

Coordinates: 21"49'16.1N 88"20'32.5E

Topography: Flat

- Site
- Gopalnagar Uttar Primary Health Sub Center
- Poultry farm
- Pathmandir (school)

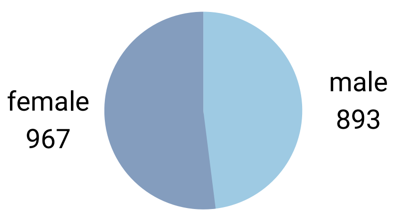
User group

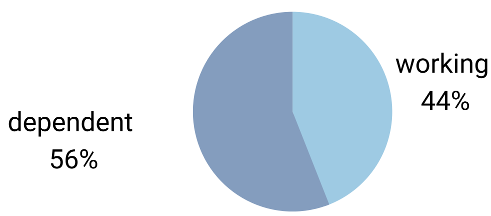
The shelter is being designed for 45 people + 35 (in extreme conditions)

Target Users
- The vulnerable communities
- People living in high risk zone.
- Poverty-stricken communities.

Local livelihood of people
- Agriculture & fishing
- Commuting (Auto-rickshaws)
- Transportation of small goods

Nature of local community
- Adaptable
- Work together
- Stay together





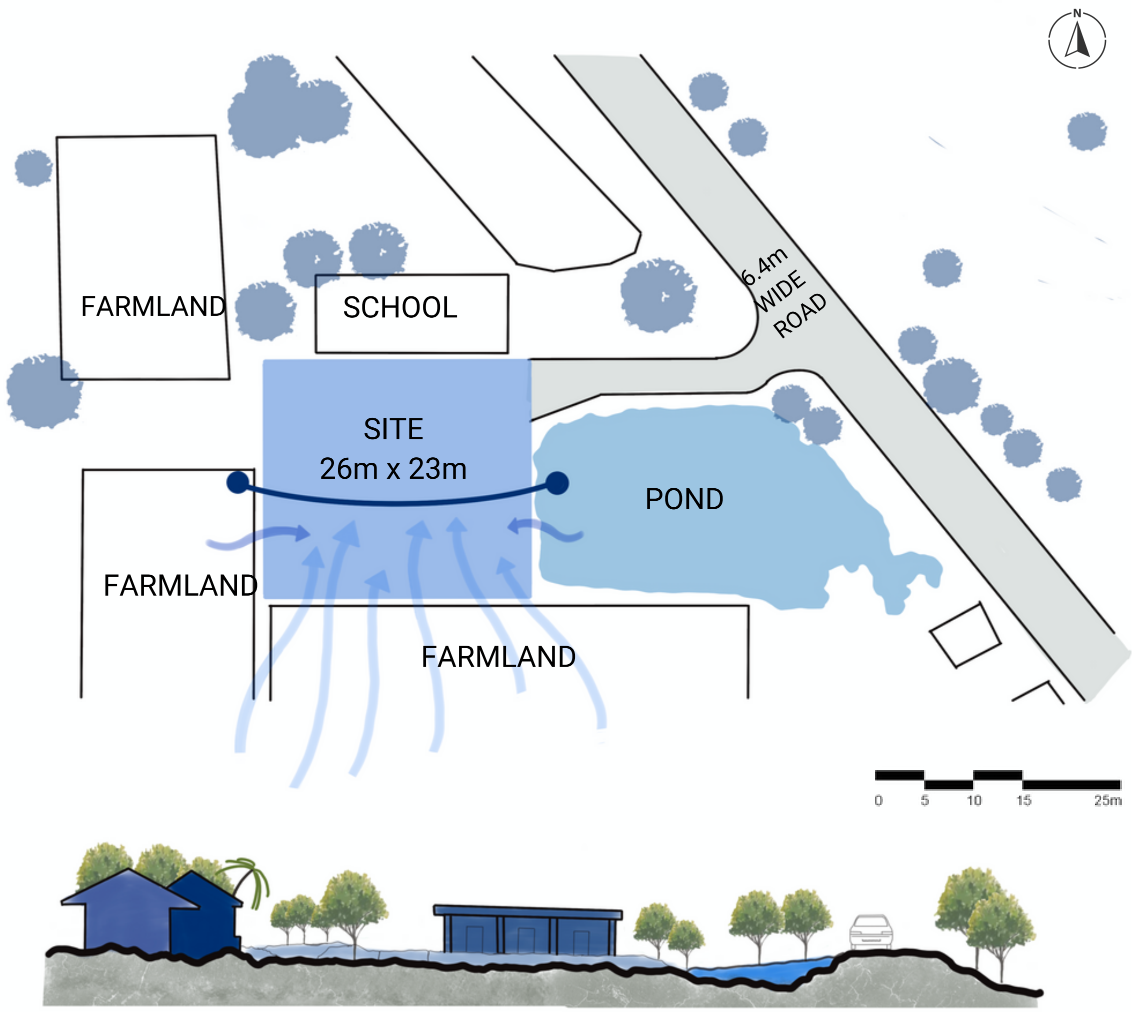


Fig 3.2 Site Plan and Site Section

Site Area: **598 sqm**
Permissible Built-up Area: 900 sqm
Permissible Ground Coverage: 40% (maximum 239.2 sqm)
Estimated Built-up Area: **236 sqm**

HOURS OF OPERATION

Vegetable Mandi Timings:
5:00 AM to 9:00 AM
4:30 PM to 8:30 PM

Weaving Timings :
10:00 AM to 4:00 PM

SPECIAL REQUIREMENTS FROM PROJECT PARTNER

- The relief shelter must be designed in compliance with the National Building Codes (NBC) and any other guidelines issued by NDMA.
- A G+1 structure not more than 7m tall; as per the context of our site.
- As per humanitarian standards, the minimum area required per person in a relief shelter is 3.5 sq.m.
- The shelter must be designed to prevent flooding and damage from high speed winds.
- The shelter should preferably be powered with renewable energy. It must be designed with a minimum of 72-hour power back.
- The shelter must have a drinking water reserve for the emergency by the Panchayat.
- The construction time should be at most one year. The use of local materials should be prioritized.
- Natural lighting and ventilation should be maximized in indoor spaces.

₹

The **CAPEX** cost of the shelter should not exceed **70,00,000 (INR).**

The **OPEX** space must be minimal as the building will be handover and managed

Energy Performance

- Achieving the goal of a Net Zero Energy Building.
- Reducing the energy performance index up to 81.2%.
- Annual energy production is 43528 kWh, which is more than the consumption of 2630 kWh

Water Performance

- Having a net zero water cycle
- Use treated greywater for flushing and irrigation.
- Reducing 135lcpd to 75lcpd by installing low flow fixtures.

Value proposition

- Design an adaptable prototype that can be used anywhere with similar conditions that have been considered for this project.

Embodied carbon

- To reduce the Total Carbon Emission factor for Roofs, Floors, Fenestration and Walls by 40% .
- Achieving this by local materials and Agrocrete

Affordibility

- Creating a primary source of income during non-disaster hours (mandi and weaving center).
- Adapting simple, low-cost design using local materials.

Innovation

- Facilitate more people during disaster hours, which is also flexible during non-disaster days for mandi/weaving purposes.

Health and Wellbeing

- Achieving an indoor operative temperature between 25 and 27 degrees as per the NBC 2016 Thermal comfort standards.
- Achieve an IAQ according to WHO, ASHRAE and NBC (2016) Standards.

Engineering operations

- Minimize the cyclone and wind impact on the structure.
- Develop shelter as a community market space during non-emergency
- Easy operability and multi-functionality of the shelter space

Architectural design

- Designing a flood and cyclone-resistant structure with self-sustainability that caters to users of both disaster and non-disaster hours.
- Create a comfortable and healthy environment during disasters

Resilience

- Providing a flood-resistant ,earthquake proof and wind mitigating structure which is self resilient in terms of food ,water and electricity

ENERGY PERFORMANCE

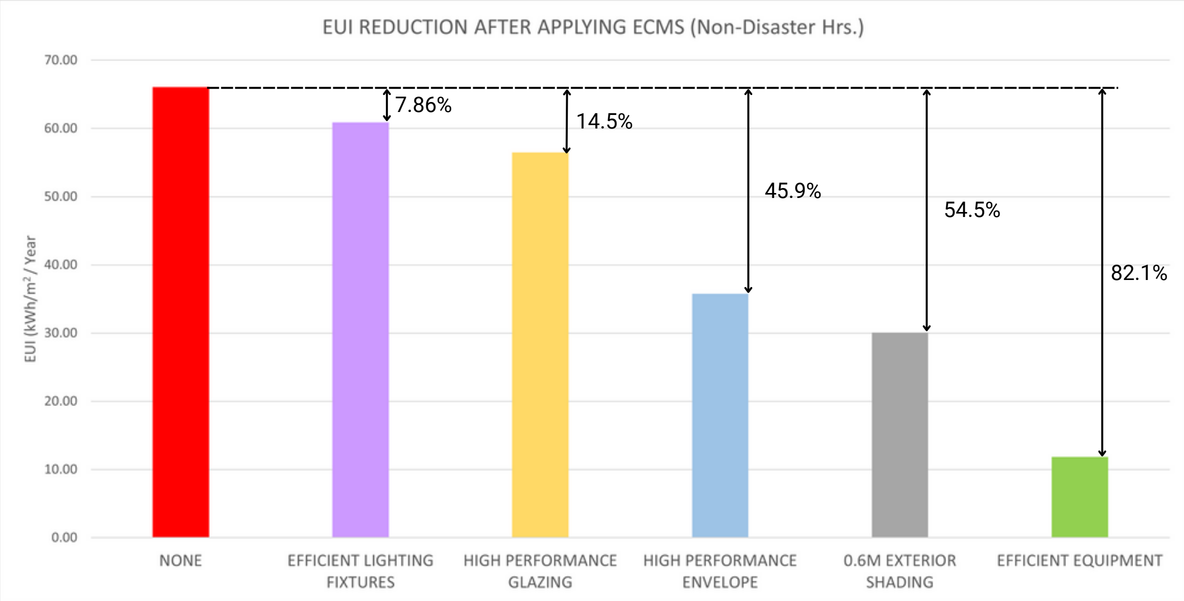
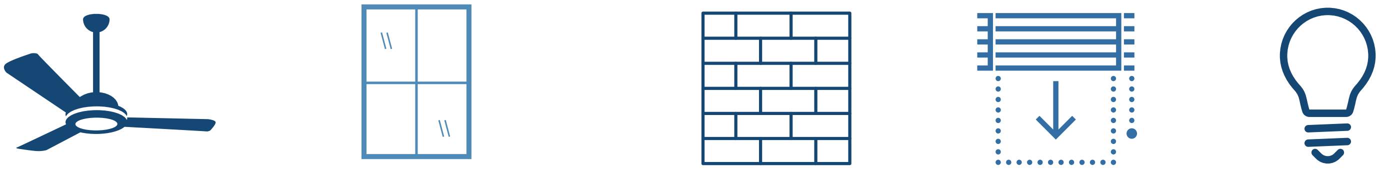


Fig. 5.1.1 EUI Changes after applying ECMs to base design

We have achieved an EUI reduction of 82.1% from our base design values by applying the following Energy conservation measures (ECMs) - Achieved EUI - 11.83 kWh/m2/Yr. from 66.08 kWh/m2/Yr.



EFFICIENT EQUIPMENT **HIGH PERFORMANCE GLAZING** **HIGH PERFORMANCE ENVELOPE** **0.6M SHADING** **EFFICIENT LIGHTING**

The specifications for the base design values and proposed design values of the ECMs can be found in the Outline Specifications, in the Appendix Table 8 and Table 9.

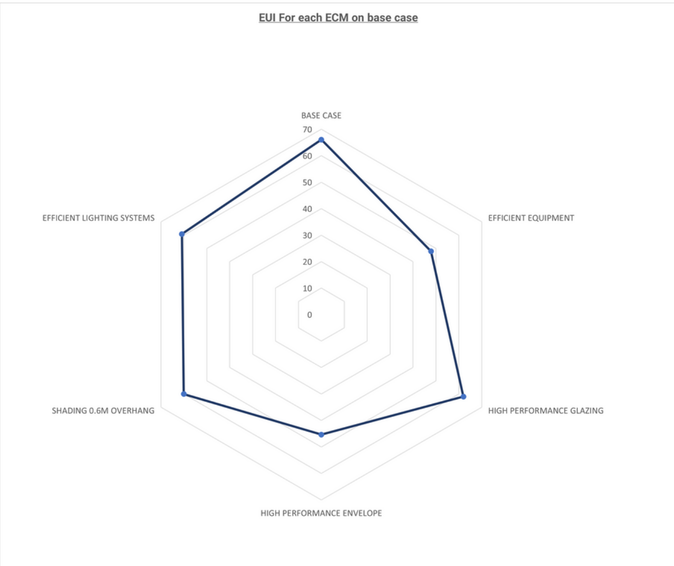


Fig. 5.1.2 EUI Changes after applying ECMs to base design individually

Fig. 5.1.2 shows how each ECM individually applied to the base design has affected the EUI (in kWh/m2/year):

- Efficient equipment has contributed the largest reduction in EUI - 27.6% from base line
  - This thoroughly justifies the higher CAPEX of more efficient equipment as it reduces the electricity charges (6.93 INR/kWh) over the year
- High performance glazing contributed the smallest reduction in EUI - 6.19%
  - While the EUI reduction is not as significant, the change in glazing specifications resulted in a drastic reduction in envelope heat gains. This can be found in Fig. 5.1.6 on page no. 8. Base case and Proposed case monthly envelope gains

The EUI during Disaster hours is slightly higher than the EUI during Non- Disaster hours as the ventilation during disaster hours is more disrupted so the fans have to run for slightly longer hours to ensure the IAQ and thermal comfort are maintained. In addition to this, it is assumed that 1/3 of the light fixtures will not be in use during disaster hours.

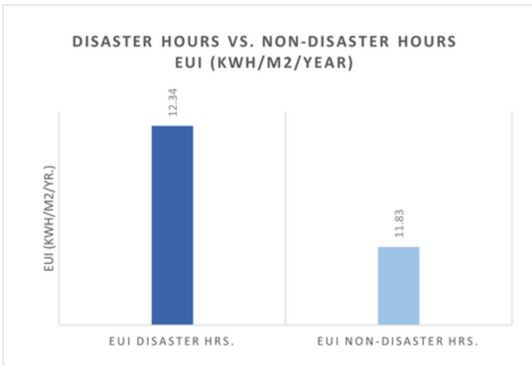


Fig. 5.1.3 EUI values for Disaster hours (L) and Non-disaster hours (R)

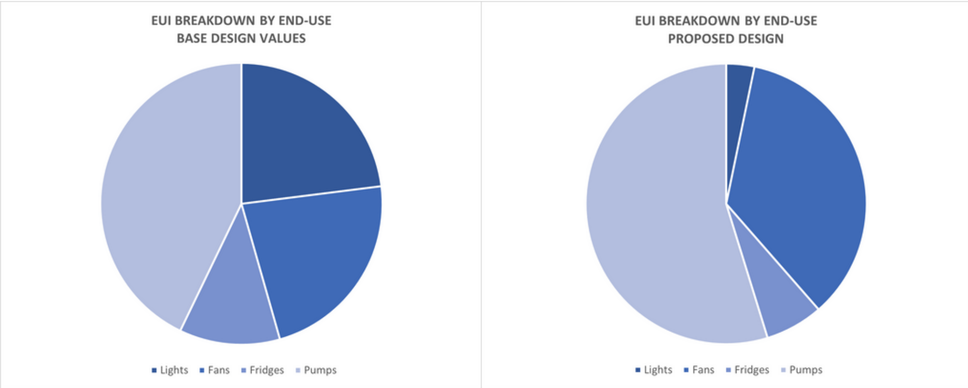


Fig. 5.1.4 EUI breakdown by end-uses for baseline and proposed designs

Fig. 5.1.4 represents the breakdown of EUI by the end-uses.

The largest reductions are seen in the **fridge and lights**, this is due to the **increase in efficiency** in both cases, hence **bringing down their electricity charges** significantly, which would offset their higher initial cost.

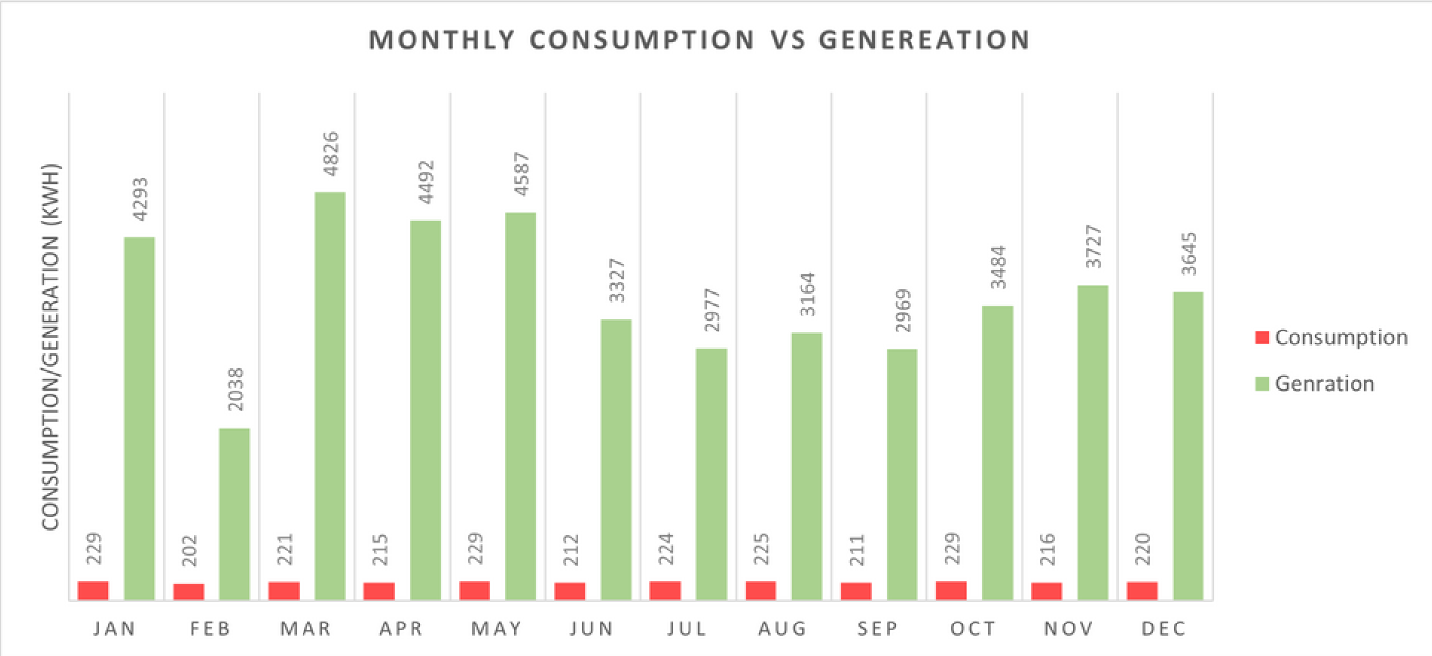


Fig. 5.1.5 Monthly Consumption vs. Generation

Fig. 5.1.5 depicts the electricity consumed and generated on a monthly basis of the shelter.

- **Average Consumption (Monthly) - 219 kWh**
- **Average Generation (Monthly) - 3627 kWh**
- **Net energy (Monthly) - +3408 kWh (+1556%)**

The excess energy produced will be stored and used during disaster hours to sustain the building for 72 Hours off-grid. Further details of this can be found in the **RESILIENCE** section and the capacity of the Solar system and its battery capacity can be found in the outline specifications in Appendix Table 9- Outline specification 2.

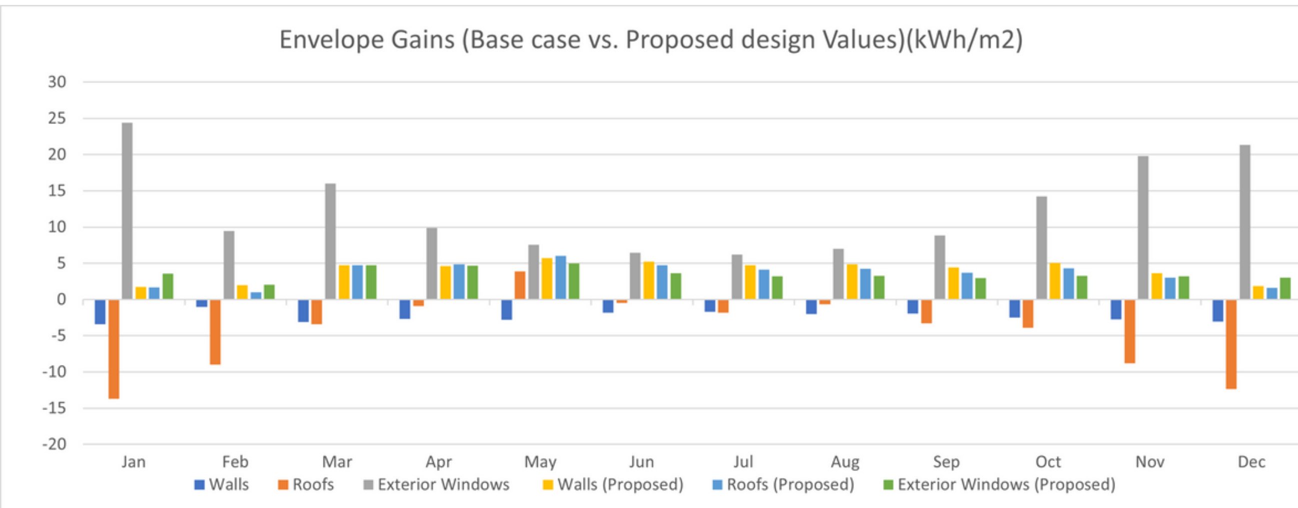


Fig. 5.1.6 Base case and Proposed case monthly envelope gains

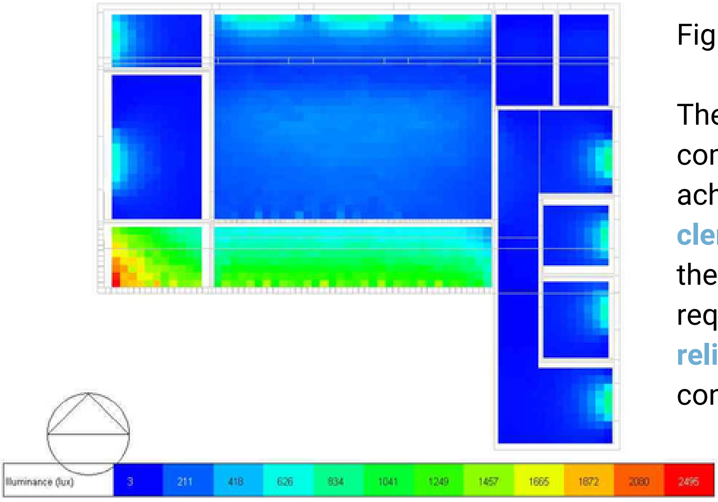


Fig. 5.1.7 Useful Daylight Illuminance (%Hrs.)

Fig. 5.1.8 shows the Illuminance (Lux)

The minimum illuminance required to achieve visual comfort is **150 lux.** In our base case design we weren't achieving this value. To tackle this, we added **clerestory windows** that allowed us to better harness the available daylight and achieve the visual comfort requirements. In addition to this, it also **reduced our reliance on artificial lighting**, bringing down the energy consumption.

Fig. 5.1.7 shows the Useful Daylight Illuminance (%Hrs.)

Majority of our building receives "Useful daylight" for **more than 60%** of the annual hours. This results in a **lesser requirement for artificial lighting** during this time. This results in **energy consumption reductions** during most of the year.
We have achieved this with a **WWR of 30%** to allow **optimum daylighting** while keeping **heat gains as low** as possible.

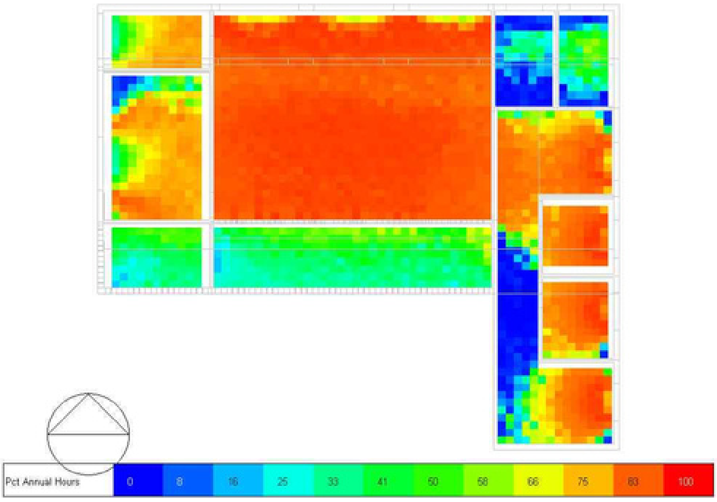
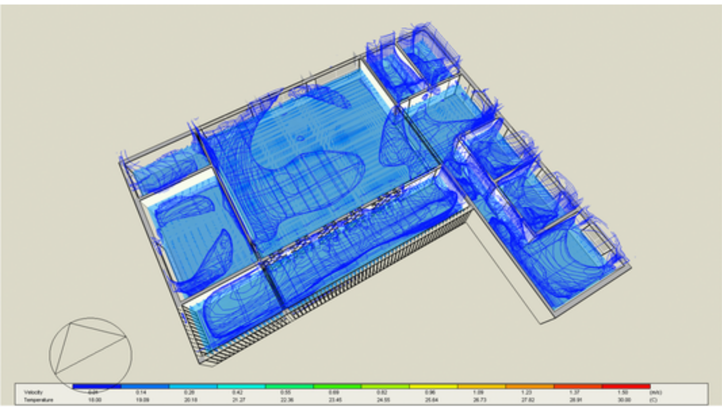


Fig. 5.1.8 Illuminance (lux)



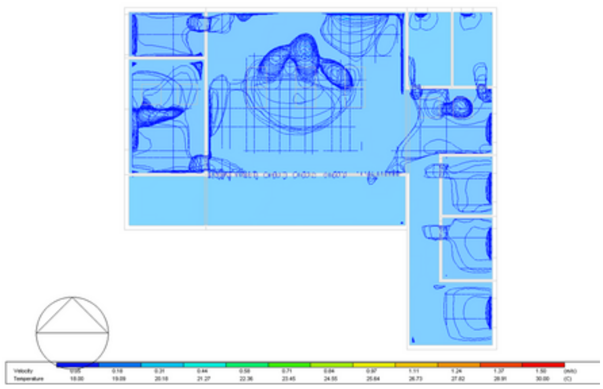


Fig. 5.1.9 CFD Analysis

- **Max. Comfortable Air Velocity (IAV) = 1.5m/s**
- **Min. IAV Requirement = 0.2m/s**
- **Achieved IAV = 0.3m/s**

The figure on the **right** shows the CFD analysis of the structure during **non-disaster hours** during which the **louvres in the north and south will be open** to maximize cross ventilation.

The figure on the **left** represents the CFD analysis during **disaster hours**. During this period, the **louvres will remain closed when the air velocity exceeds 8.m/s.** However, all the spaces still receive the required amount of ventilation.

WATER PERFORMANCE

We propose a net zero water structure, as there is no municipal supply of water. Taking advantage of the rainfall, a rainwater harvesting system has been incorporated. The use of low-flow fixtures will also help reduce **135 lpcd to 75 lpcd**. We are also treating grey water, which will be used for flushing and irrigation. Root zone filtration system is an addition to the site. We have tried to follow the 3R principle: reduce, reuse and recycle water.

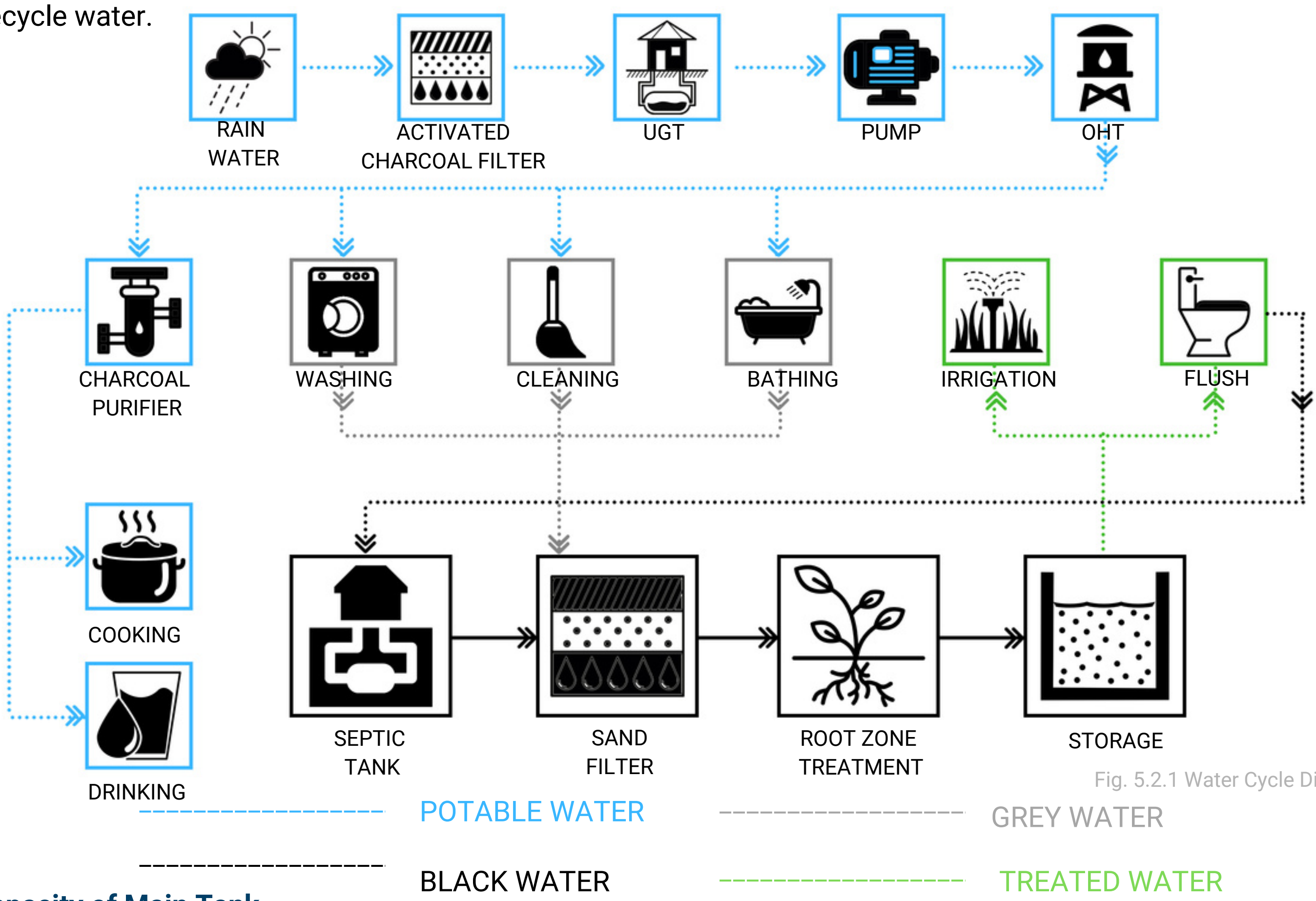


Fig. 5.2.1 Water Cycle Diagram

Capacity of Main Tank

Total fresh water demand in may = **1,08,000 litres** Per day demand in may = 1,08,000/31 = 3484 ltr= **3500 ltr**
Total tank storage capacity is twice the actual, so water storage required is 3500 x 2 = 7000 litres = **7 cum**
underground tank dimensions , **height =2.45 m** and **length = breadth = 1.7 m.**
Overhead tank for 2 days capacity , SINTEX TANK OF 15000 LITERS CAPACITY IS USED TO ELIMINATE THE COST OF CONCRETE OVERHEAD TANK.
Storage tank for harvested rainwater and filtered grey water of capacity 180 Cum is provided under the structure.

Root Zone Treatment System

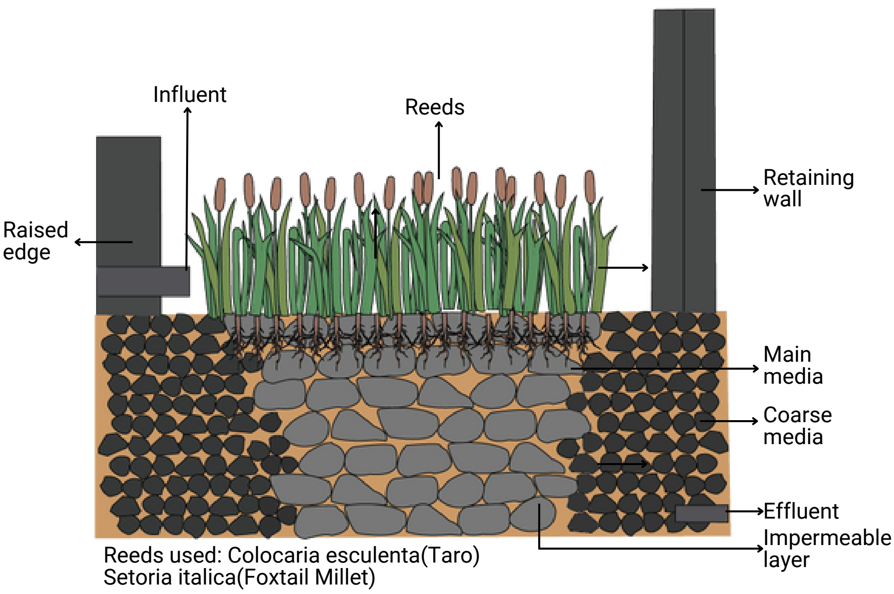


Fig. 5.2.2 Root zone Filtration system

Root zone treatment system is designed to treat grey water generated by 45 people.
Considering 1.5 sqm of reeds per one person
1.5 x 45 = 67.5 sqm of reeds
total reed bed = **67.5 sqm**
Located in the southwest side of the site.

Reeds used are :
1. *Colocaria Esculenta* (taro plant)
2. *Setaria Italica* (foxtail millet)

WATER CALCULATIONS

Water harvesting Sources	Area	Runoff coeff
Roof Surfaces	250	0.75
Hardscape areas	162	0.75
Softscape areas	106	0
Effective catchment area	**309**	

Table 5.1 Catchment Area

ROOF MATERIAL -
REINFORCED CEMENT CONCRETE
PAVEMENT MATERIAL -
CONCRETE PAVERS

Domestic Use		Irrigation Use	
Use LPD/Head	37.5	L/m^2	1
Number of people	45	Area m^2	106
Total LPD	1687.5	Max LPD	106

Table 5.2 Water Consumption for domestic and irrigation use

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing	30%	1013	1,013	
Washing	20%	675	675	
Cleaning house	8%	270	270	
Washing Utensils	16%	540	540	
Others	2%	68	34	34
Drinking	4%	135		135
Cooking	3%	101		101
Toilet Flushing	17%	574		574
Total		3375	2,531	844

Table 5.3 End uses - Disaster Hours

Water Consumption baseline estimate along with reuse pathways for
DISASTER SCENARIO

(during disaster, bathing & washing activities
are added to the baseline estimate)

		CONSUMPTION						WATER SOURCES				
Month	Days in month	Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Bore water (L)	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	1,04,625	90%	-	5%	164	1,04,789	-	89610	78,469	26,156	63289
Aug	31	1,04,625	80%	-	5%	164	1,04,789	-	86520	78,469	26,156	123489
Sep	30	1,01,250	50%	-	50%	1,590	1,02,840	-	72306	75,938	25,313	168892
Oct	31	1,04,625	75%	-	30%	986	1,05,611	-	36153	78,469	26,156	177903
Nov	30	1,01,250	20%	-	90%	2,862	1,04,112	-	7725	75,938	25,313	157454
Dec	31	1,04,625	0%	-	90%	2,957	1,07,582	-	927	78,469	26,156	129267
Jan	31	1,04,625	0%	-	90%	2,957	1,07,582	-	1545	78,469	26,156	101699
Feb	28	95,344	20%	-	90%	2,695	98,039	-	4635	71,508	23,836	79803
Mar	31	1,04,625	50%	-	90%	2,957	1,07,582	-	6180	78,469	26,156	56869
Apr	30	1,01,250	90%	-	90%	2,862	1,04,112	-	12669	75,938	25,313	41363
May	31	1,04,625	100%	-	90%	2,957	1,07,582	-	31518	78,469	26,156	43768
Jun	30	1,01,250	90%	-	90%	2,862	1,04,112	-	72306	75,938	25,313	87899
Total							12,58,734	-	4,22,094	9,24,539		87,899

Table 5.4 Water Balance - Disaster Hours

Water Consumption baseline estimate along with reuse pathways for
NON - DISASTER SCENARIO.

(during non disaster time, bathing and washing
activities are removed from baseline estimate)

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing		0	-	
Washing		0	-	
Cleaning house	8%	135	135	
Washing Utensils	16%	270	270	
Others	2%	34	17	17
Drinking	4%	68		68
Cooking	3%	51		51
Toilet Flushing	17%	287		287
Total		844	422	422

Table 5.5 End uses - Non-Disaster Hours

	Days in month	CONSUMPTION						WATER SOURCES				
Month		Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Bore Water (L)	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	52,313	90%	-	5%	164	52,477	-	89610	13,078	13,078	50211
Aug	31	52,313	80%	-	5%	164	52,477	-	86520	13,078	13,078	97333
Sep	30	50,625	50%	-	50%	1,590	52,215	-	72306	12,656	12,656	130080
Oct	31	52,313	75%	-	30%	986	53,298	-	36153	13,078	13,078	126013
Nov	30	50,625	20%	-	90%	2,862	53,487	-	7725	12,656	12,656	92907
Dec	31	52,313	0%	-	90%	2,957	55,270	-	927	13,078	13,078	51642
Jan	31	52,313	0%	-	90%	2,957	55,270	-	1545	13,078	13,078	10995
Feb	28	47,672	20%	-	90%	2,695	50,367	22,819	4635	11,918	11,918	0
Mar	31	52,313	50%	-	90%	2,957	55,270	36,011	6180	13,078	13,078	0
Apr	30	50,625	90%	-	90%	2,862	53,487	28,162	12669	12,656	12,656	0
May	31	52,313	100%	-	90%	2,957	55,270	10,674	31518	13,078	13,078	0
Jun	30	50,625	90%	-	90%	2,862	53,487	-	72306	12,656	12,656	31475
Total							6,42,374	97,666	4,22,094	1,54,090		(66,191)

Table 5.6 Water Balance - Non-Disaster Hours

- **1.5HP submersible pump** used to pump water from UGT to OHT
- **1HP centrifugal pump** used to pump water to root zone filtration and storage tank
- During disaster and non-disaster scenarios a net positive water cycle was achieved by implementing rainwater harvesting, treating grey water using root zone filtration system and low flow fixtures

BAMBOO CHARCOAL FILTER FOR RAINWATER

This kind of charcoal is readily available here and its effectiveness in filtration is very high. The water first passes through rocks and coarse sand to filter out any big particles, and then travels through bamboo charcoal which retains impurities. The water then flows through further filtration by that are fine sand and Polyvinyl chloride mesh and this filtered water is passed out and sent to storage. Through bamboo charcoal which retains impurities.

It is cheaper than an electric water purifier and the charcoal bamboo filter is easy to make because all the materials are locally available, which in-turn reduces the cost of it.

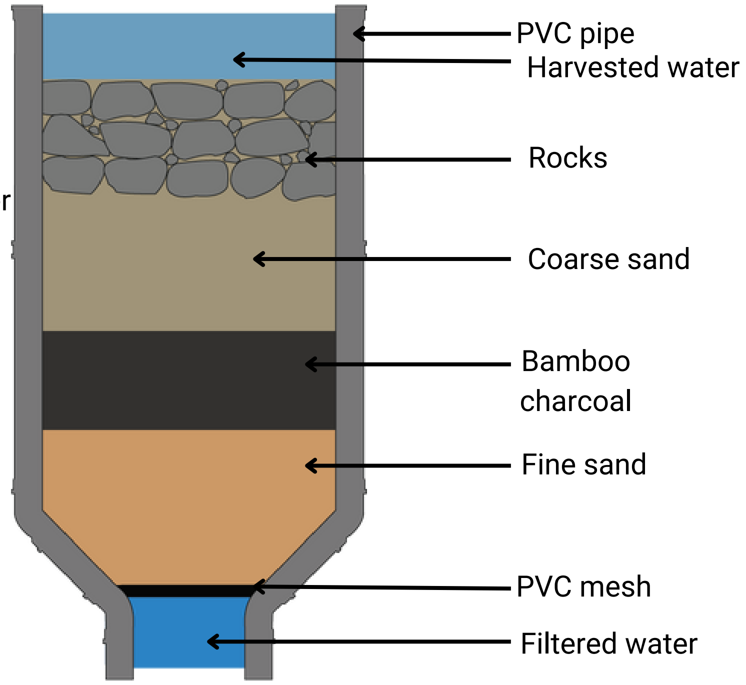


Fig. 5.2.3 Bamboo charcoal filter

Comparison between BASE CASE and PROPOSED CASE of Water Consumption

Total consumption of water in **BASE CASE = 22,44,909 liters** annually.
(please refer to appendix, table 4,5,6 and 7 for calculations of base case water consumption).
Note:
In **base case**, the lpcd value is **135 liters**, as low flow fixtures were not used, but rainwater harvesting and grey water treatment is done.

Total consumption of water in **PROPOSED CASE** = **12,58, 734 liters** anually.
(please refer to table 6.9 for reference for calculations of proposed case water consumption).
Note:
In **proposed case**, the lpcd value is **75 litres**, low-flow fixtures are used and rainwater harvesting and grey water treatment is implemented, which makes it a **NET-POSITIVE WATER CYCLE.**
Therefore, the proposed case is **43.93% MORE EFFICIENT** than the base case.

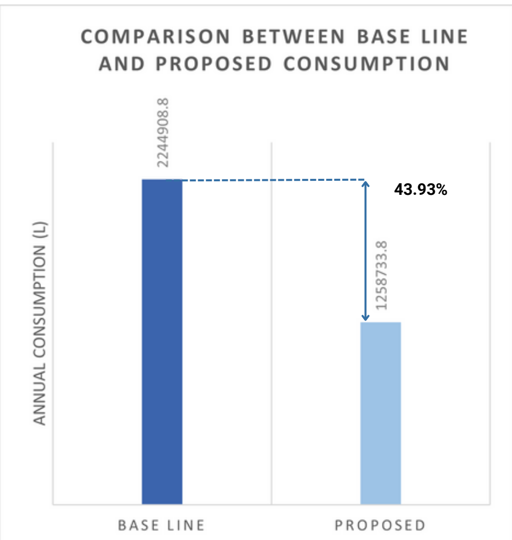


Fig. 5.2.4 Base case vs Proposed Case Comparison

CONCLUSION:

In both disaster and non-disaster hours, annually we are achieving **net-positive water cycle**. The excess water which is stored on site by the end of the year is around **66KL**, will be sent to the **Agricultural land** right beside the site, which will help the local farmers.

EMBODIED CARBON

Narrative for reducing Carbon Emissions

Materials

1. Agrocrete (Hollow blocks)

- Embodied carbon is -0.15 kg/CO_2 e
- U-Value of hollow blocks is 1.3-1.6 W/m2.K
- Strength > 5MPa

2. Portland Pozzolana Cement (PPC)

- PPC consists of 15-35% pozzolanic material, 4% gypsum and the rest is clinker.
- Embodied carbon of PPC is 0.67 kg CO_2/kg

Strategies

- Materials will be sourced from local vendors to reduce the distance travelled for transportation.
- Using alternate construction materials such as bamboo and agrocrete over traditional bricks.
- Proposing to plant Mangroves near the wetlands to absorb CO_2
- Keeping the circulation space minimum to reduce materials.

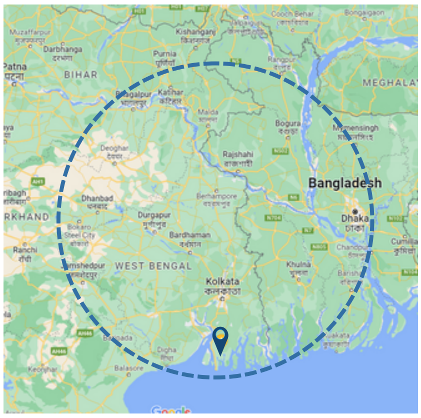
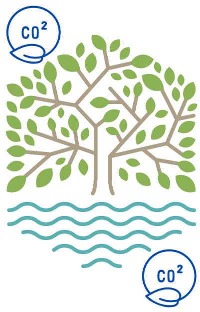
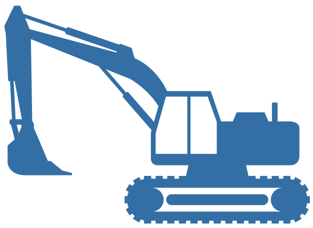


Fig. 5.3.1 Transportation Radius



Machinery used during construction

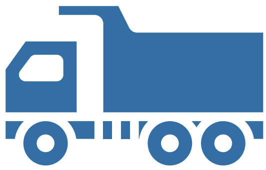
Machinery used for 8hrs each day



Earth Excavator

67 kW
67 x 8 = 536 kWh

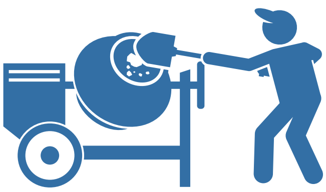
Carbon emission per day
125 kg/CO_2 e



Dump Truck

112 kW
112 x 8 = 896 kWh

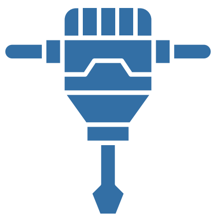
Carbon emission per day
209 kg/CO_2 e



Concrete Mixer

Manual mixer

Carbon emission per day
0 kg/CO_2 e



Drill Jack Hammer

1 kW
1 x 8 = 8 kWh

Carbon emission per day
1.8 kg/CO_2 e

Total Carbon emissions during construction per day **335.8 kg/CO_2 e**

Total Carbon emissions from Steel used in Beams, Columns and Slab - 94,592 kg-CO_2e

Surplus Renewable energy produced - 43,427 kWh/year

No.of years required to mitigate the Carbon emission from steel - **2 years 2 months**

Carbon Emissions Summary

System Type	Baseline				Proposed			
	Material emissions (kg -CO_2 e)	Transport 1 (kg -CO_2 e)	Transport 2 (kg -CO_2 e)	Total (kg -CO_2 e)	Material emissions (kg -CO_2 e)	Transport 1 (kg -CO_2 e)	Transport 2 (kg -CO_2 e)	Total (kg -CO_2 e)
Wall	55.2	1.7	0.1	56.9	7.4	0.8	0.3	8.5
Roof	598.8	4.5	1.6	604.9	568.0	4.3	1.5	573.9
Floor	598.8	4.5	1.6	604.9	568.0	4.3	1.5	573.9
Fenestration	754.6	2.3	1.0	757.9	59.3	0.4	0.1	59.7
Structural	234.0	3.2	0.4	237.6	112.5	1.5	0.4	114.4
	Grand Total emissions per functional unit (kg -CO_2 e)			2262.2	Grand Total emissions per functional unit (kg -CO_2 e)			1330.4

Table 5.7 Embodied Carbon Calculations

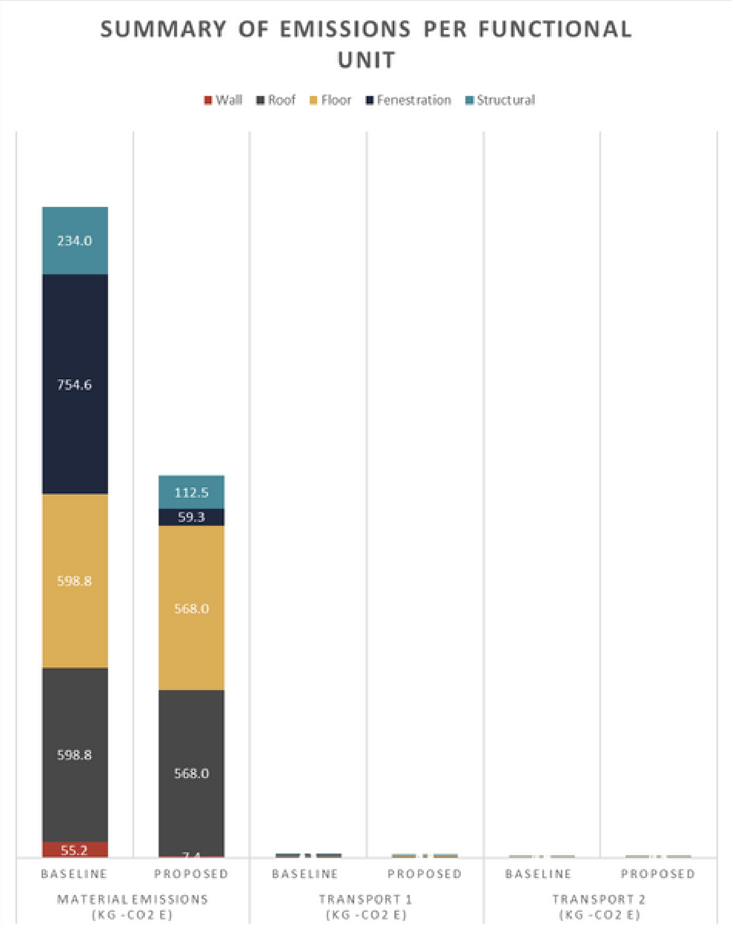


Fig. 5.3.2 Summary of emissions

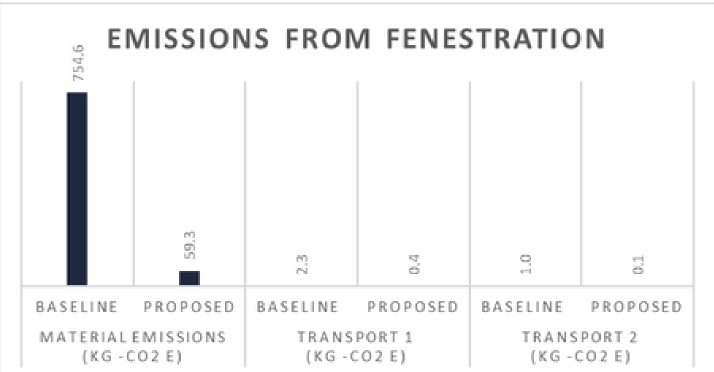


Fig. 5.3.3 Fenestration emissions

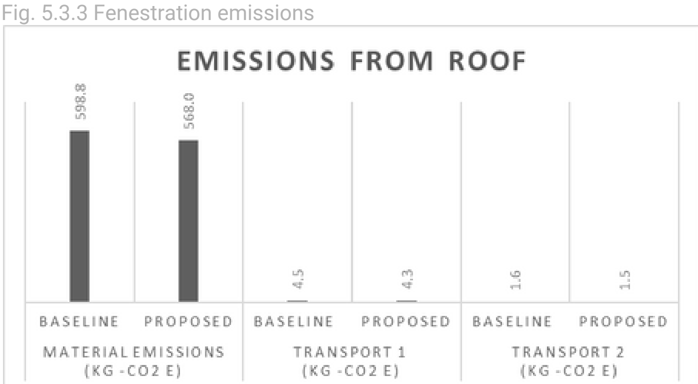


Fig. 5.3.4 Roof emissions

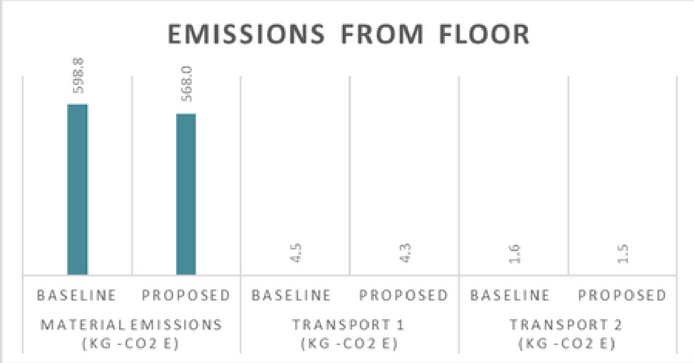


Fig. 5.3.5 Floor emissions

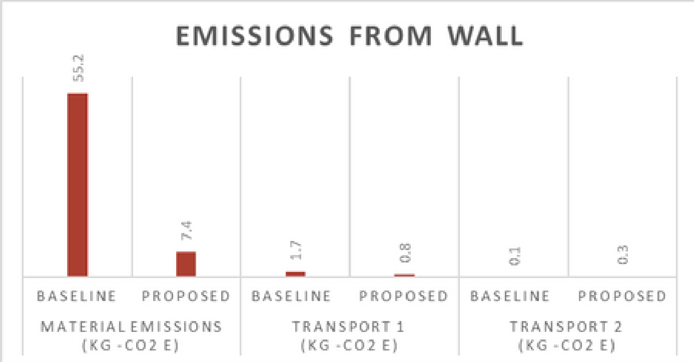


Fig. 5.3.6Wall emissions

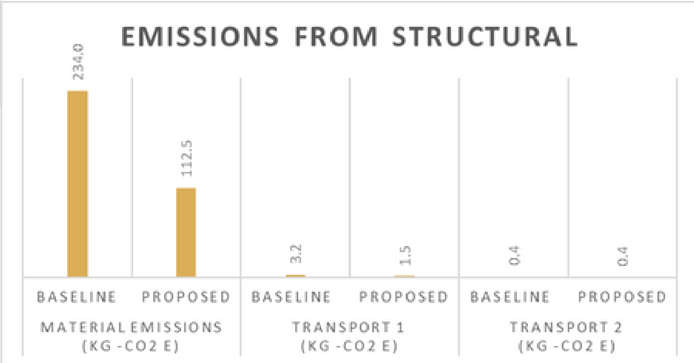


Fig. 5.3.7 Structural emissions

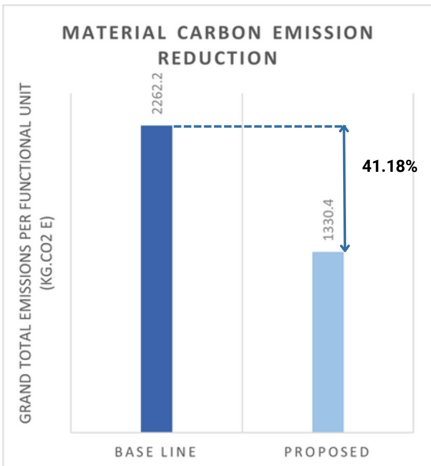


Fig. 5.3.8 Base Line vs Proposed Carbon Emissions

RESILIENCE

Prevailing risks in the region:

- The site resides in the flood plains of the Ganga, where the river meets the Bay of Bengal, a region that is prone to flooding, earthquakes, high speed winds and diseases.

Resilience from or through

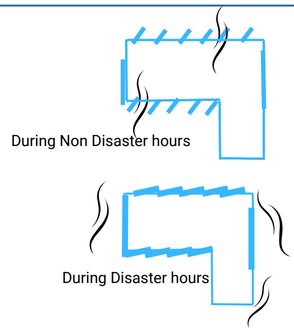
High Speed Winds | Flood | Self Reliance | Diseases | Earthquakes | Engineering

ISSUES FROM HIGH SPEED WIND

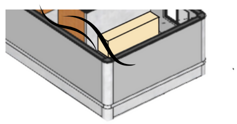
1.Winds of the magnitude of 200 km/hr can damage the structure and its surroundings.
2.Can cause disruption of electricity and uprooting of trees.
3. Uprooting of roof and crumbling of walls because of excessive pressure of winds can also be caused.

STRATEGIES

- An innovative façade design using flaps has been incorporated, with a buffer space that closes off during a disaster and stops cross ventilation.



- The walls of the building have been chamfered to form an aerodynamic structure, reducing structural damage to the building through high-speed winds.



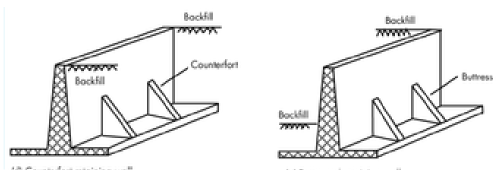
ISSUES FROM FLOODS

1.Site is low lying thus prone to undulations which can lead to severe structural damage

2. The structure has to be able to withstand intense water forces and protect the inhabitants from being caught in these floods

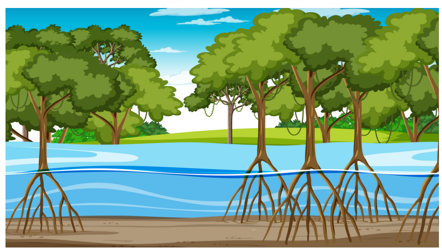
Strategies

- The boundary will be protected by retaining wall which will reduce the flood water speed. Trees with strong soil holding capacity will be planted along the boundary to hold the soil in place.



- The building has been raised on a 1.2m plinth followed by a 2.7m stilts to prevent flood water from entering the building.

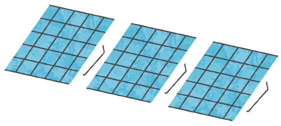
- Proposing to plant mangroves around wetlands surrounding the site which will result in the water percolation in the neighborhood to be increased thus preventing floods in the area. Also mangroves will decrease flood speed around site.



SELF RELIANCE

ENERGY- The structure will be self reliant in terms of electricity for 3 days
WATER PERFORMANCE - The structure will be self reliant in terms of water performance for 2 days

STRATEGIES



- Solar PV panels have been used to make the structure self reliant in terms of electricity during disasters
- The battery capacity is 500A which can support the structure for 3 days in terms of electricity(Refer Appendix, table - 9 Outline specifications -2)

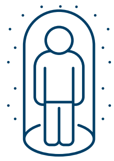
- Harvested rain water and treated grey water makes the building self reliant in terms of water for 30 days
- Root zone treatment has been used to treat grey water that will be used for flushing and irrigation.
- All this makes the proposed case 43.93% more efficient than the base case (Refer page no.22)

ISSUES FROM DISEASES

1. Diseases such as diarrhea, malaria are common during floods in the area
2. Providing a place for them to isolate during these testing times is necessary
3. Spread of these diseases can start epidemics in the area

STRATEGIES

- Isolation room has been provided to contain contagious disease.
- Multipurpose rooms have been provided, which can turn into treatment or consultancy room during disaster

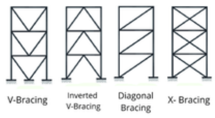


ISSUES FROM EARTHQUAKE

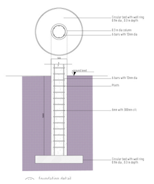
1. Site located in high seismic zone (Zone 4)
2. Seismic activities can greatly affect the integrity of the structure
3. The walls can crack and topple due to shifting seismic plates

STRATEGIES

Bracing has been provided on the stilt level to provide support to the building during earthquakes



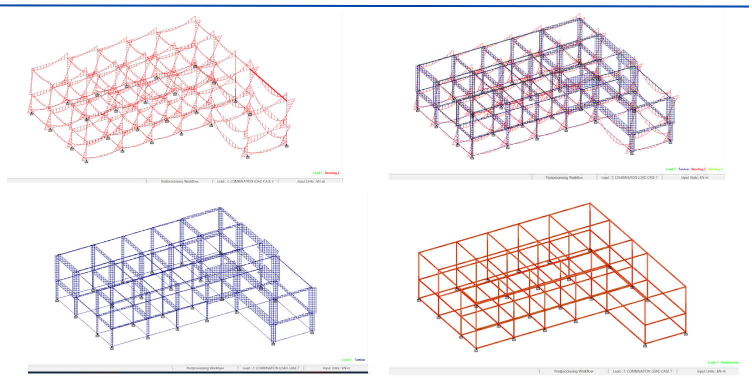
3m well foundation has been used holding the structure on the ground



RESILIENCE THROUGH ENGINEERING

1. Making a structure that can withstand forces of different disasters like floods, cyclones and earthquakes
2. These disasters can cause serious structural damage to the structure if measures are not taken towards it

STRATEGIES



Maximum deflection in the structural analysis of the frame is 21.069mm under the seismic loading condition, lower than the permissible deflection of 30mm according to IS 1893: 2002, Part-I

Wind Effect Reduction

Referring the studies done by *Jacopo Banchetti, Paolo Luchini, and Maurizio Quadrio Published in Cambridge University Press journal*, a reduction of 10% in wind friction is observed by providing a curved smooth surface which help reduce effects of strong winds, the corners of the our building facing the winds have been chamfered too to achieve the same.

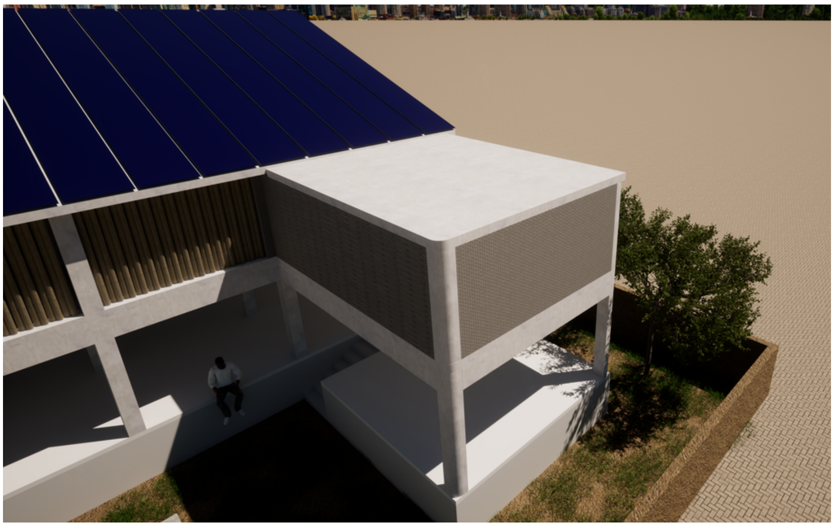


Fig 5.5.1 Chamfered edged of the structure

Seismic analysis

The structure lies in seismic zone IV, so to stiffen the structure and develop tolerance towards seismic load, an SMRF frame structure is provided.
The observed maximum deflection in the structural analysis of the frame is 21.069mm under the seismic loading condition, and the allowable deflection is 30 mm per the standards mentioned in IS 1893: 2002, Part-I. Thus making the structure safe to inhabit against earthquakes.

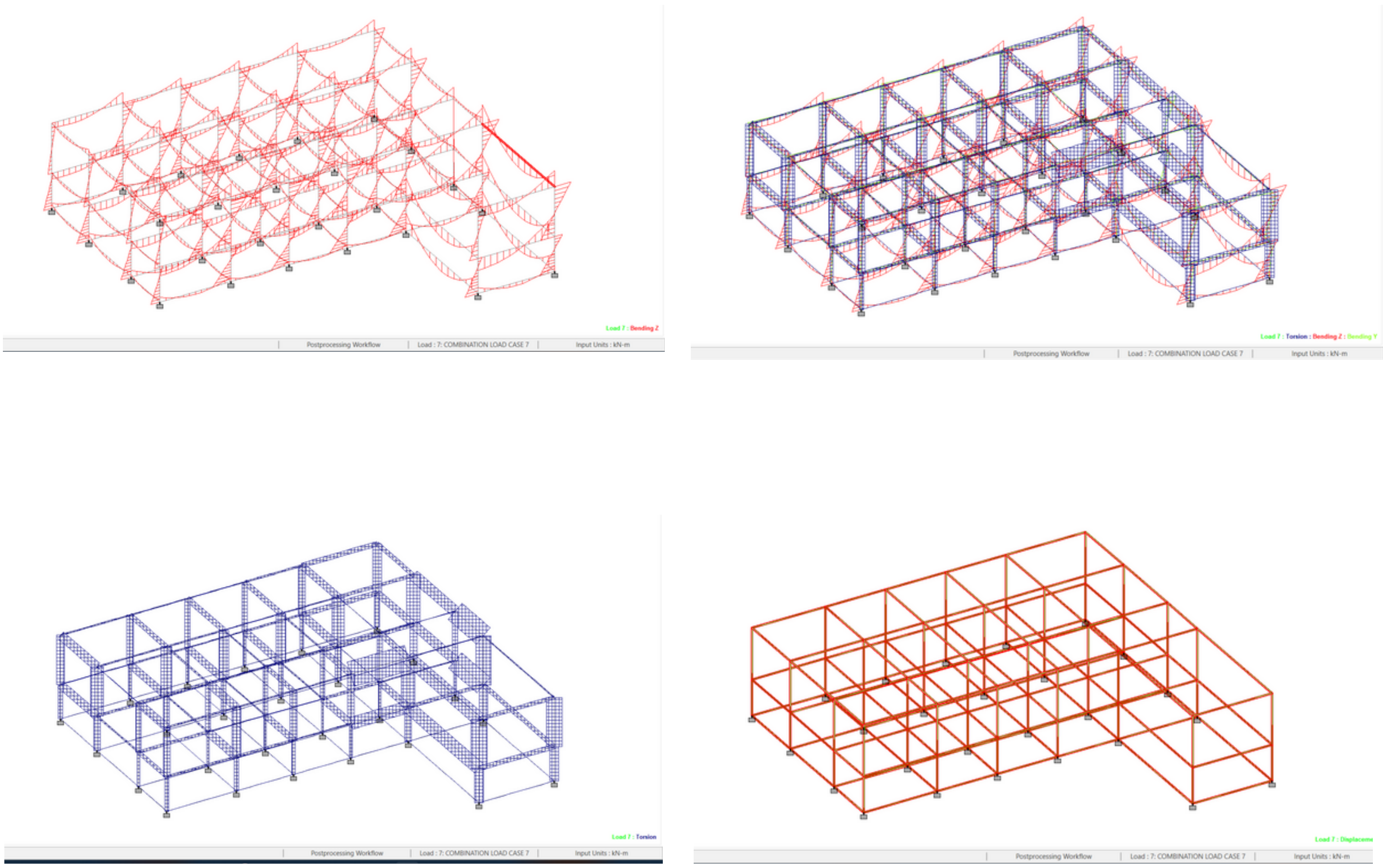


Fig 5.5.2 Staad. Pro Bending moment analysis

Post-Disaster Maintenance following a cyclone or any other natural disaster. The below mentioned maintenance procedures should be undertaken to ensure the safety and functionality of the disaster shelter:

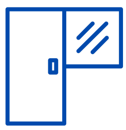
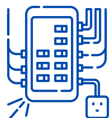





- Inspection: The first step in post-disaster maintenance is to inspect the shelter thoroughly for any damages. The inspection should cover the walls, roof, doors, windows, and other structural components for any cracks, leaks, or damages. Any damage found should be immediately reported and repaired by a qualified professional.
- Debris Removal: After a cyclone, debris and fallen objects can block access to the shelter, making it inaccessible to those who need it. Therefore, the immediate removal of debris is essential to ensure the shelter's accessibility.
- Cleanliness: Cyclones and hurricanes can cause flooding and water damage, which can lead to the growth of mold and bacteria. It is necessary to clean the shelter and ensure that there is no moisture or water inside the shelter. The cleaning should cover the floors, walls and any ventilation systems.
- Emergency Supplies: During post-disaster maintenance, the emergency supplies such as food, water, medical equipment, and tools should be inspected and replaced if necessary. These supplies should be kept up to date and in proper working order at all times.
- Emergency Communication: The shelter's emergency communication equipment such as radios or mobile phones should be checked for functionality to ensure they are working correctly.
- Emergency Exits: The emergency exits should be checked for functionality and cleared of any obstructions to ensure easy and quick evacuation during emergencies.

General Maintenance and regular maintenance of the shelter is crucial to ensure its functionality during emergencies.

- Cleaning: Regular cleaning of the shelter and its surroundings, including the floors, walls, ceiling, and ventilation systems.
- Doors and Windows: The shelter's doors, windows, and other openings should be checked regularly for leaks and drafts. Any issue found should be immediately reported and repaired by a qualified professional.
- Electrical System: The electrical system including wiring, lighting fixtures, and switches should be inspected and maintained regularly to prevent malfunctions and ensure safety.
- Plumbing System: The plumbing system including faucets, toilets, and drains, should be maintained regularly to prevent blockages and leaks.
- Roof and Drainage System: The shelter's roof, gutters, and drainage systems should be inspected and maintained regularly to prevent water damage and leaks.
- Emergency Equipment and Supplies: The emergency equipment and supplies stored in the shelter including first aid kits, flashlights, batteries, and water should be inspected and maintained regularly to ensure that they are up to date and functional.


ARCHITECTURAL DESIGN

DESIGN PROCESS

The main aim of our design was to provide thermal comfort and visual comfort to the users of the community resilient shelter at the time of disaster. We approached our designing process first by considering the sun path and focusing on reducing the exposed west facade.
3 main anchor points deemed crucial by SEEDS: roof, kitchen, and stilts were considered too. Openings were looked into accordingly on the north and south facades as the multipurpose hall was predicted to be the most used and versatile area occupying space. The south facade is has a large overhang to reduce the heat entering the structure which also acts as our buffer space for cattle and goats or even more occupants in the area in time of disaster.

Form Development from Base case

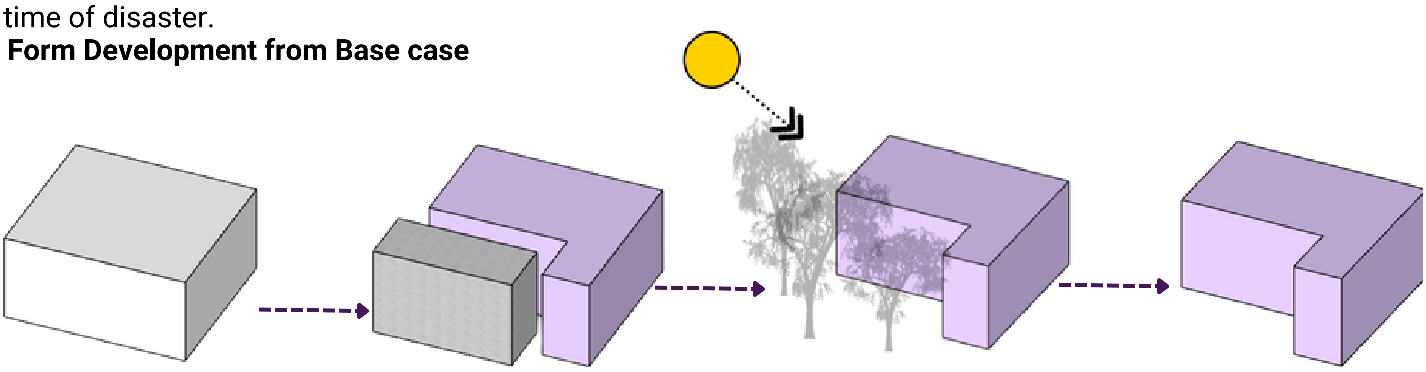
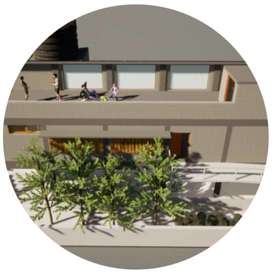


Fig 5.6.1 Form Development



To properly light the interiors, maximum openings are placed on the north façade and clerestories have been used. Most of the spaces, that have less occupancy and don't require openings have been placed on the east side which also helps reduce heat gain.

Material substitution
- Agrocrete, a carbon negative material for walls instead of burnt brick or AAC blocks.
- Use of low carbon concrete mix by using flyash, GGBFS, slag

Solar panels are installed on the roof to produce off-grid solar energy which will be stored for usage during disaster and non disaster times.

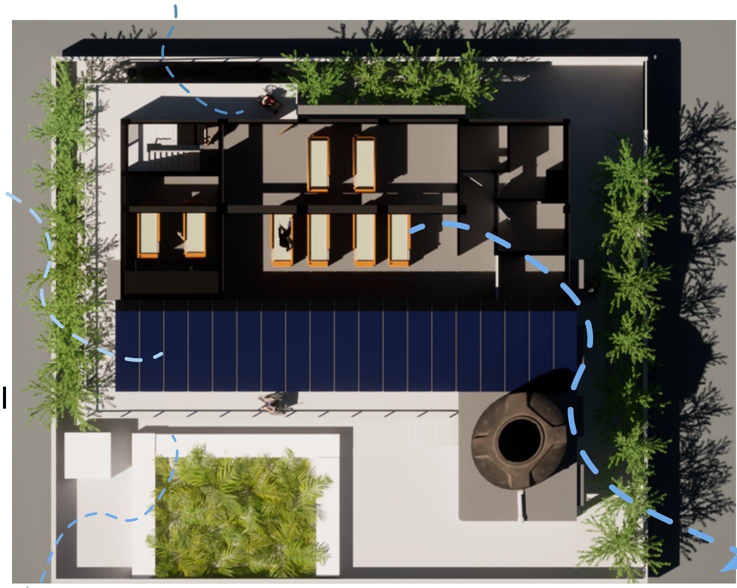
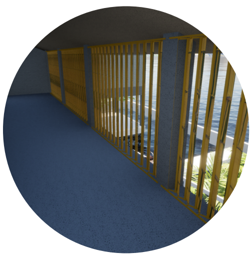


Fig 5.6.2 Rendered site plan cut at first floor

Innovative furniture design to accommodate more people during disaster for an area with less space



Innovative façade design and bamboo shutters have been implemented for cross ventilation which can be closed off during disaster hours entirely to prevent the uprooting of the structure.

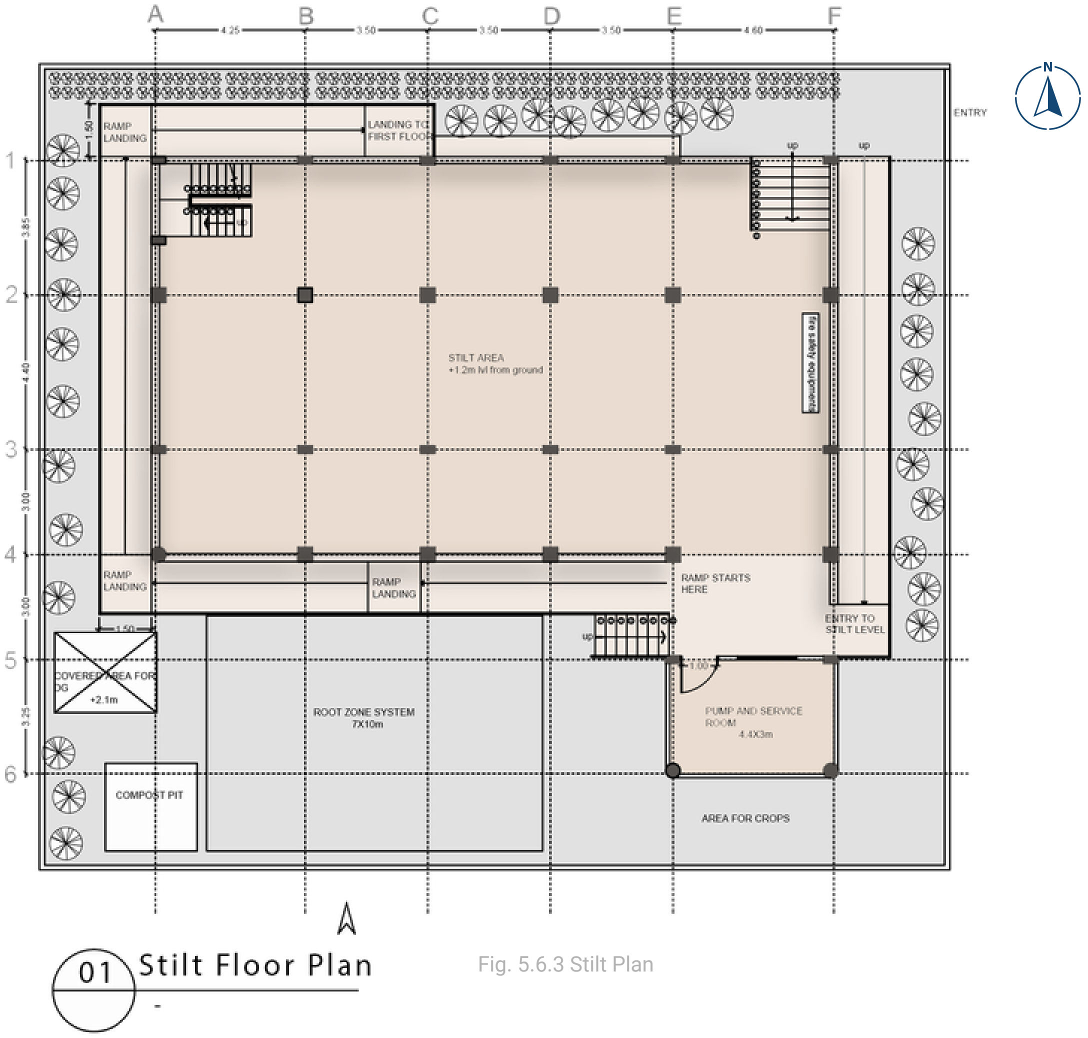


Fig. 5.6.3 Stilt Plan

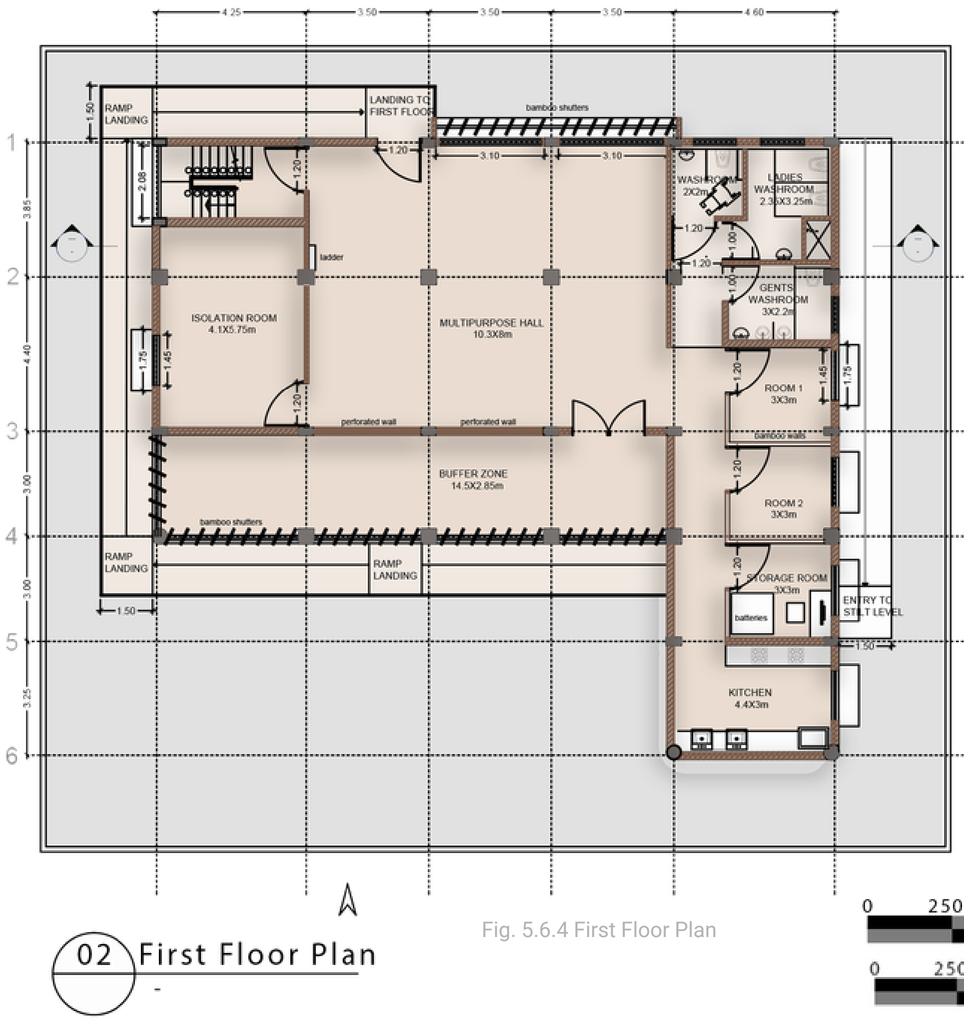
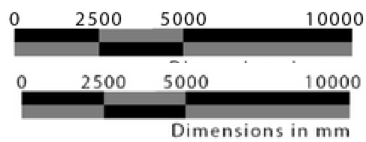
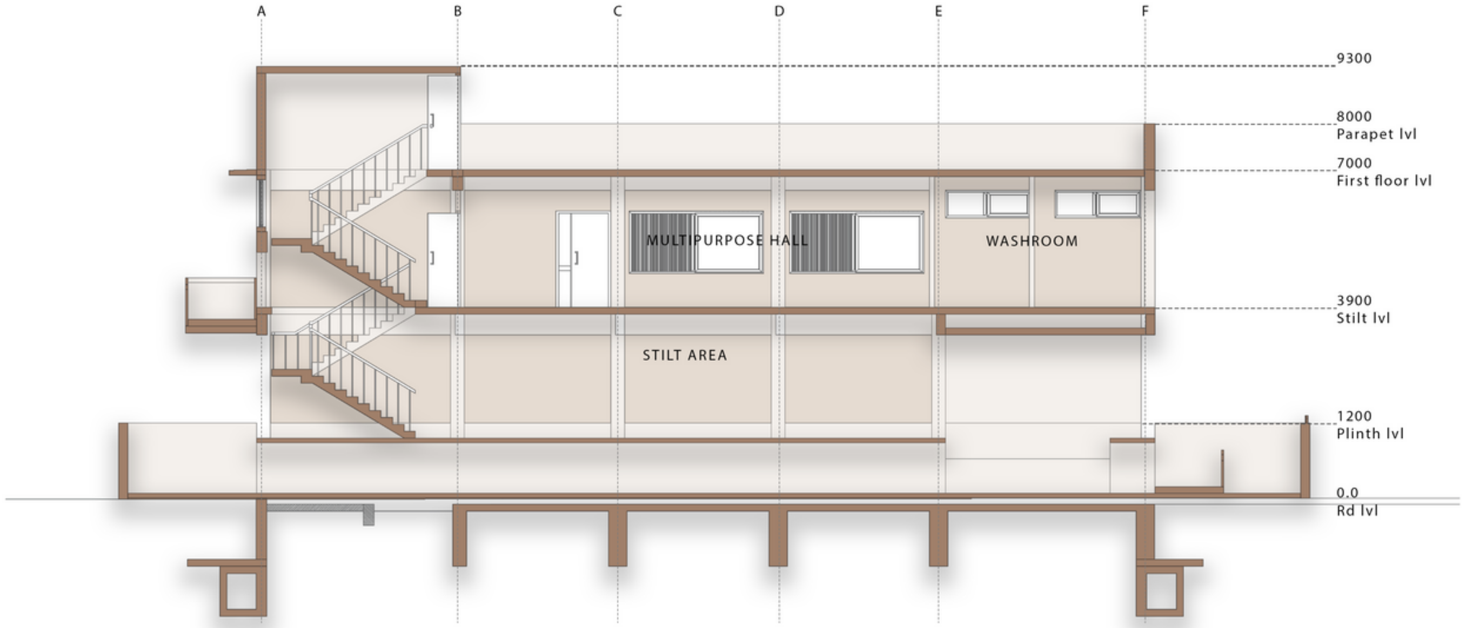


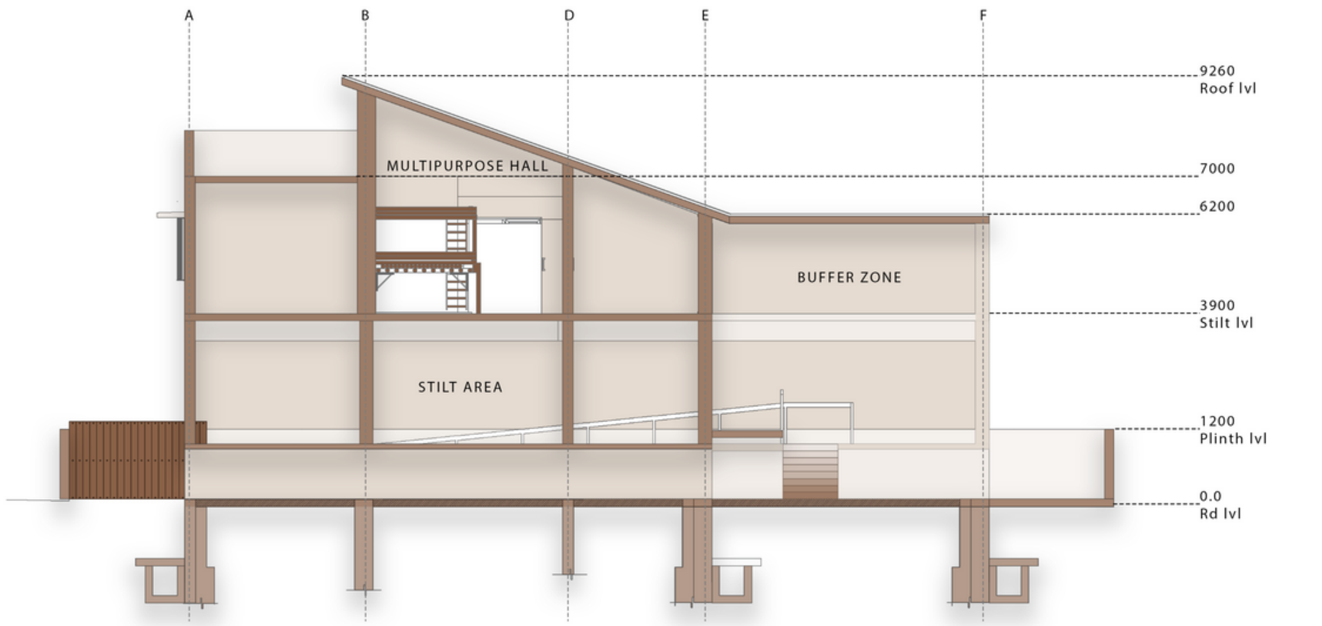
Fig. 5.6.4 First Floor Plan





Transverse Section-AA’

Fig. 5.6.5 Transverse Section



Longitudinal Section-BB’

Fig. 5.6.6 Longitudinal Section

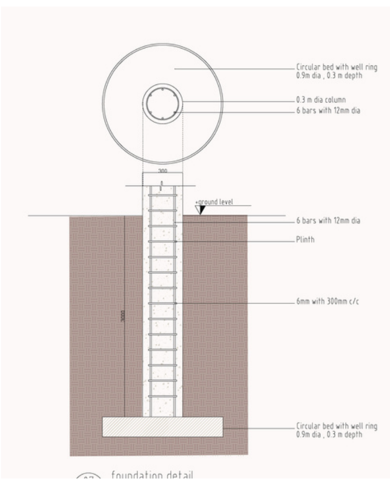
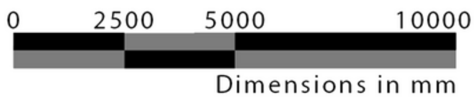


Fig. 5.6.7 Foundation Detail



VIEWS

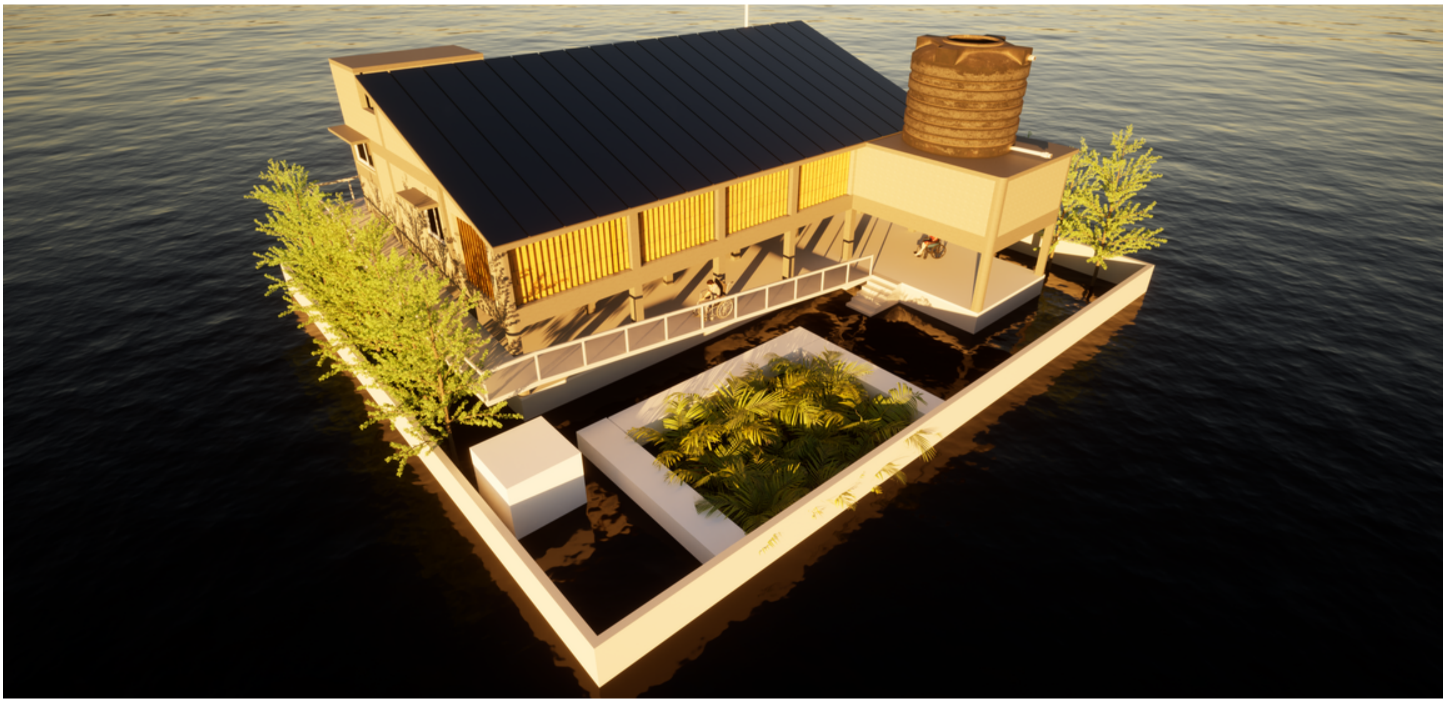
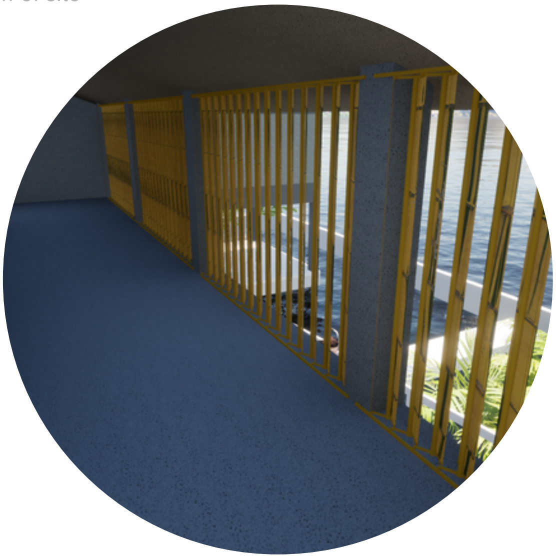


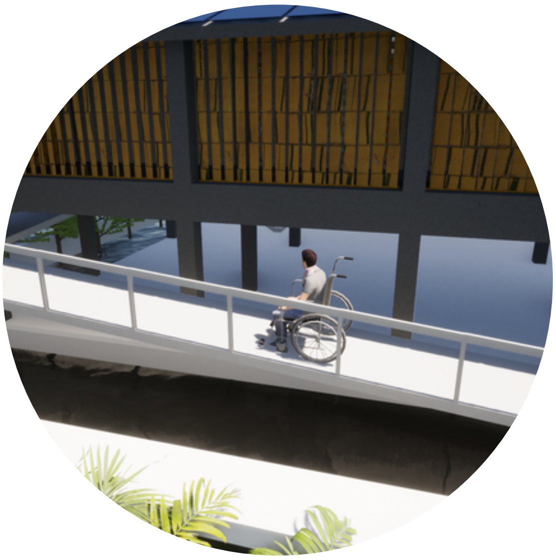
Fig. 5.6.8 Axonometric view of site

Innovative Bamboo Furniture



Innovative flap facade

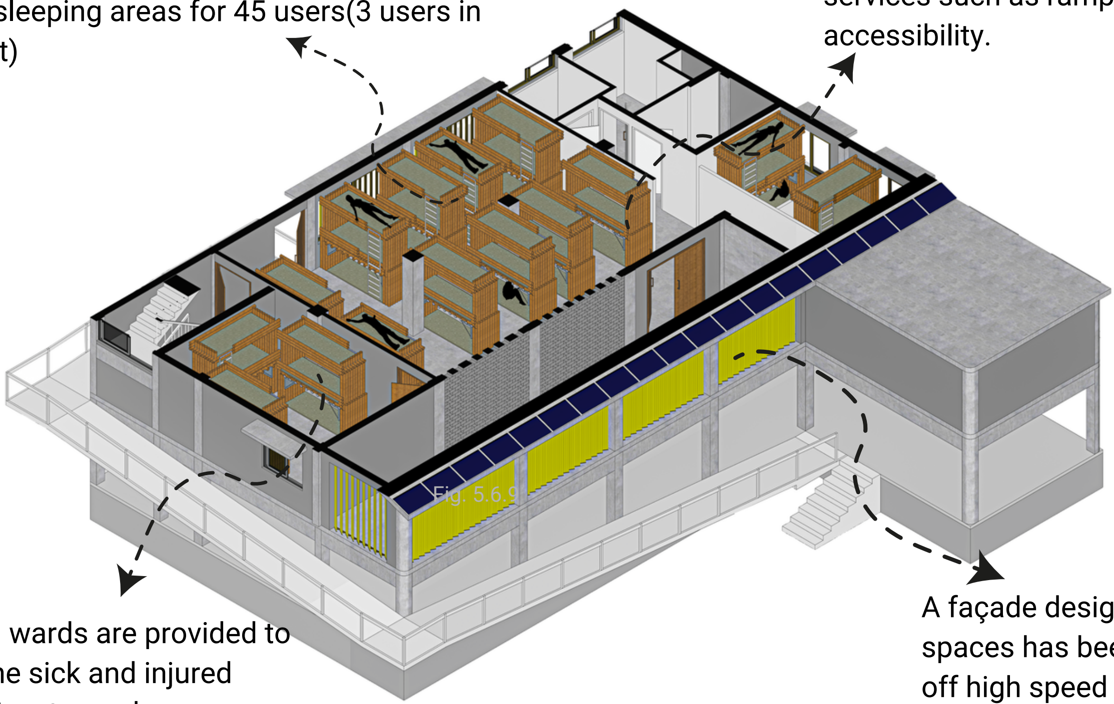
Agrocrete Perforated wall



Ramp for Specially Abled

We have proposed 15 modular furniture system units which would be joined and stacked together as one unit (like a Lego system) to provide sleeping areas for 45 users(3 users in each unit)

Multifunctional spaces such as the multipurpose hall. The whole structure is equipped with barrier free services such as ramps for easy accessibility.



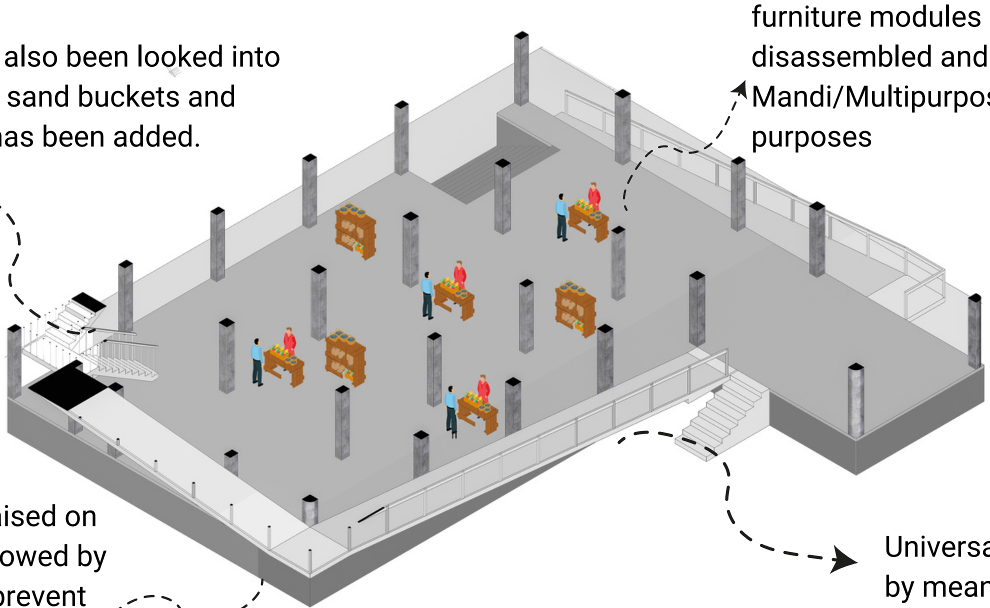
Isolation wards are provided to attend the sick and injured during disaster and non-disaster hours.

A façade design with buffer spaces has been provided to cut off high speed winds from entering the structure

Fig. 5.6.10 Axonometric View Of Building

During non-disaster hours the furniture modules can be disassembled and used in Mandi/Multipurpose hall for different purposes

Fire safety has also been looked into and a place for sand buckets and extinguishers has been added.



The building is raised on a 1.2m plinth followed by a 2.7 m stilts to prevent flood water to enter the building .

Universal Access is provided by means of a 1:12 Slope ratio ramp .

Fig 5.3 Floor Activity

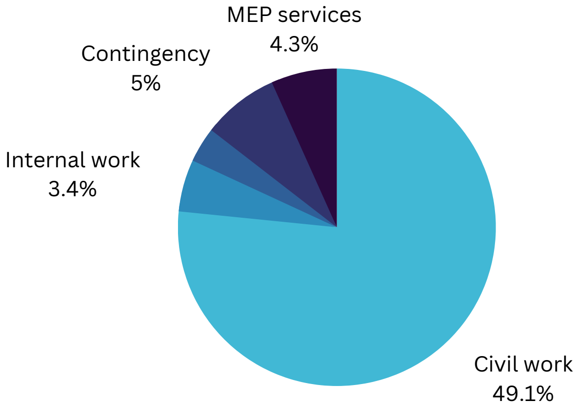
AFFORDABILITY

Comparison of total project cost:

S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount in Million INR	%	Amount (INR per sqm)	Amount in Million INR	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased	2.34	26.6%	2,600	2.34	26.6%	2,600
2	Civil Works	Refer Item A, Civil works in Cost	4.32	49.1%	4,798	3.70	42.1%	4,114
3	Internal Works	Refer Item B, Civil works in Cost	0.30	3.4%	332	0.50	5.7%	559
4	MEP Services	Refer Item C, Civil works in Cost	0.38	4.3%	420	0.88	10.0%	980
5	Equipment & Furnishing	Refer Item D, Civil works in Cost	0.00	0.0%	-	0.08	0.9%	89
6	Landscape & Site Development	Refer Item E, Civil works in Cost	0.20	2.3%	224	0.00	0.0%	2
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	0.26	5.0%	289	0.26	5.0%	287
	TOTAL HARD COST		**7.80**	**90.7%**	**8,662**	**7.77**	**90.4%**	**8,630**
8	Pre Operative Expenses	Cost of Permits, Licenses, Marke	0.50	5.7%	556	0.50	5.7%	556
9	Consultants	Consultant fees on a typical Proje	0.50	5.7%	556	0.50	5.7%	556
10	Interest During Construction	Interest paid on loans related to th	-	0.0%	-	-	0.0%	-
	TOTAL SOFT COST		**1.00**	**11.4%**	**1,111**	**1.00**	**11.4%**	**1,111**
	TOTAL PROJECT COST		**8.80**	**100.0%**	**9,773**	**8.77**	**99.7%**	**9,741**

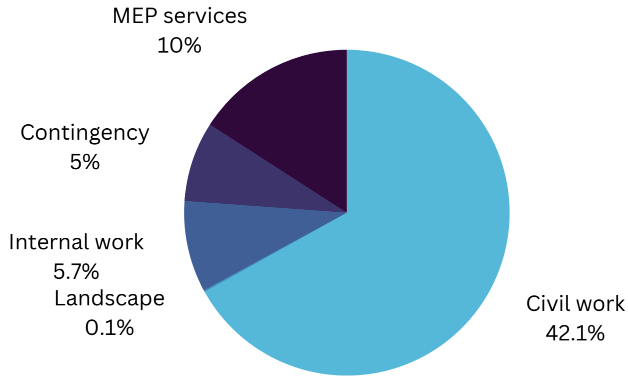
Table 5.8 Cost Estimate Summary

The cost of the proposed case is lower than the base case which estimated at 1.8% due to the following:



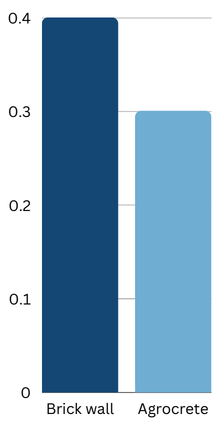
BASE CASE ESTIMATES

Fig. 5.7.1 Base case estimate



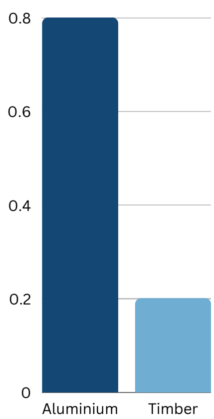
PROPOSED CASE ESTIMATES

Fig. 5.7.2 Proposed case estimate



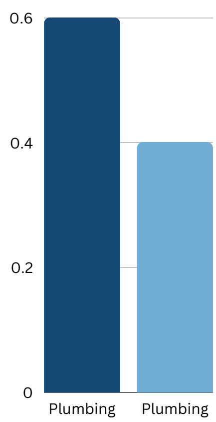
FACADE COST BREAKDOWN

Fig. 5.7.3 Facade Cost Breakdown



FENESTRATION COST BREAKDOWN

Fig. 5.7.4 Fenestration Cost Breakdown



PLUMBING COST BREAKDOWN

Fig. 5.7.5 Plumbing Cost Breakdown

Base case Proposed case

- Reduction in costs by opting for Timber instead of Aluminum for fenestration
- Agrocrete is used instead of traditional bricks resulting in cost reduction in the facade and internal work
- The right sizing of the elements in electrical and plumbing services by various design strategies, like using low flow fixtures in case of plumbing and energy-efficient lighting for electrical.
- No insulation is used in the wall which reduces the internal work cost by a considerable amount.

ENERGY INTERVENTION-
- Optimized use of daylight using clerestory reduces the need for artificial lighting, hence reducing electrical loads.
- Rightsizing of lighting is done so that the required amount of illumination is given in the area.

DESIGN INTERVENTION-
- Using local materials like bamboo as the primary material for facades and furniture reduces transportation and construction costs.
- By innovating furniture that takes up less space.

WATER INTERVENTION-
- Overhead tank supply to reduce energy consumption utilizing gravity-fed plumbing
- Efficient plumbing systems are used.

Renewable Energy Cost Evaluation :

The feasibility of investment is assessed by accounting for the costs of the hardware, equipment, installation costs, and indirect labor costs for each of the orientations individually.
Thirty mono/poly solar panels have been installed, which produce 10KW and meets the requirement with a capital cost of INR 5,06,080 and a payback period of 8.5 years.
The operation and maintenance are estimated at 1% of the capital expenditure, and generation degradation of 1% annually is considered for the solar panels.

5.7.6 Economic Feasibility of Solar PV Array

LCC ANALYSIS
Life cycle cost analysis is used to enable decision-making that is beneficial to the
developer and the tenants/owner.
Life cycle cost analysis for a period of 25 years, for the base case, compared to the proposed case incurred an incremental cost of 0.88 million INR NPR for energy conservation measures, to improve the environment.
The **life cycle cost decreased by 11.6%**
i.e., from 7.57 to 6.69
The **capex cost decreased by 1.8%%**

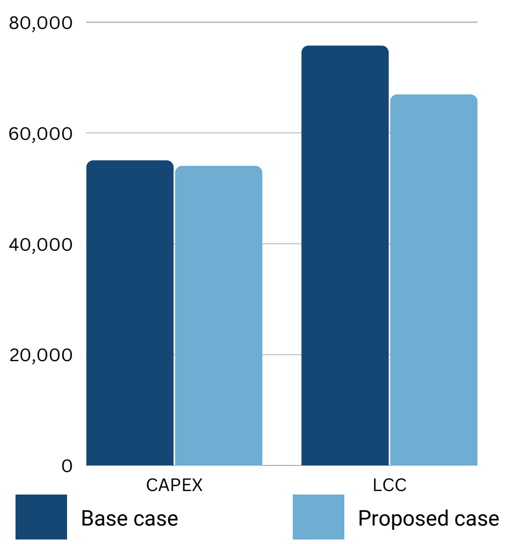


Fig. 5.7.7 Base vs. proposed case - CAPEX and LCC

INNOVATION 1

MODULAR FURNITURE SYSTEM

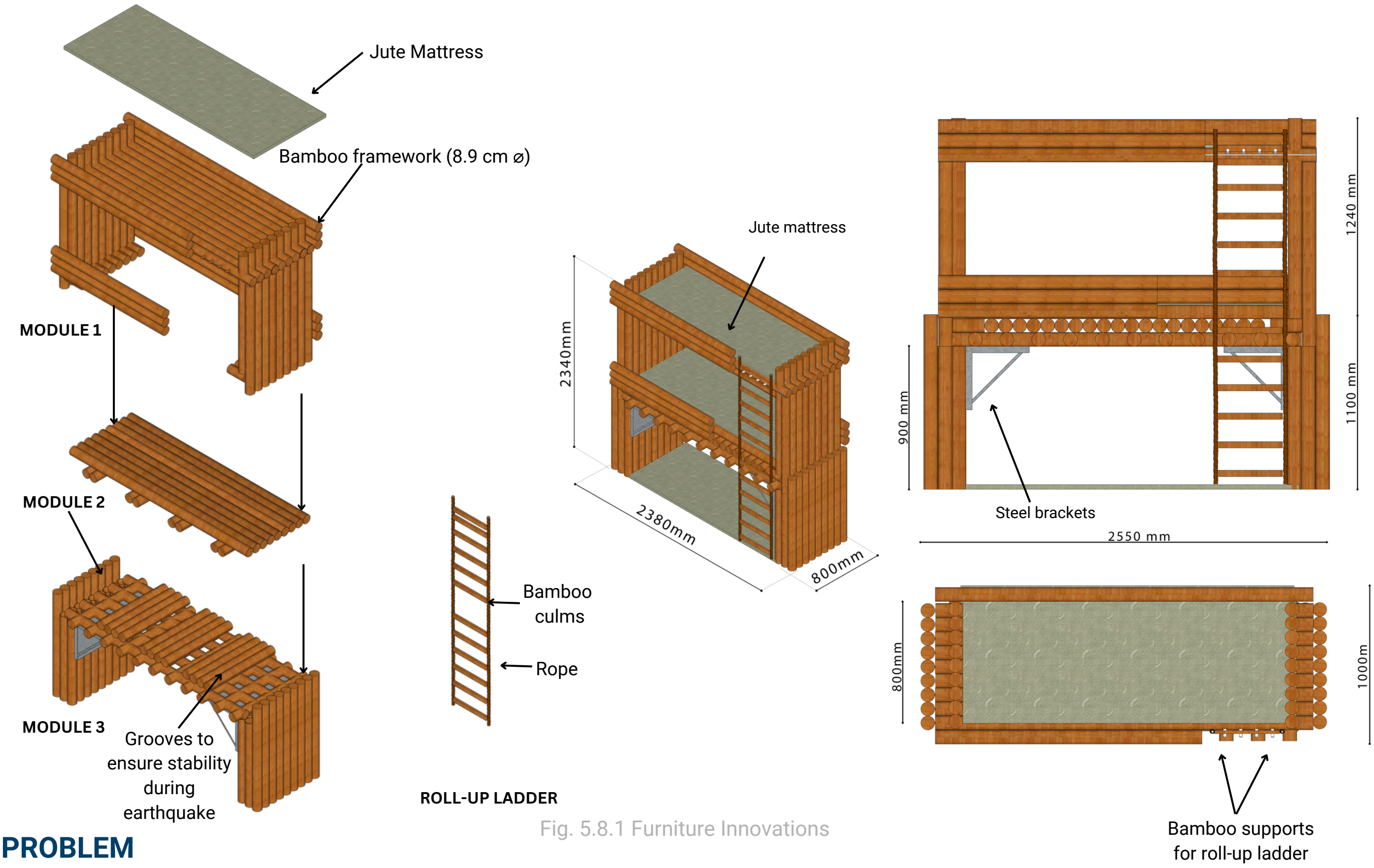


Fig. 5.8.1 Furniture Innovations

PROBLEM

Lack of space to accommodate 45+ users (in case of overcrowding).

OPPORTUNITY

Utilization of mandi/weaving/knitting during non-disaster days for income generation.

DISASTER USE

During disaster hours these bamboo modules would be joined and stacked together as one unit to provide sleeping areas for 3 users, making optimum use of space. The system ensures a high level of strength and stability by the use of groove joinery, foldable metal brackets and intertwined thick bamboo present ensure a rigid, secure framework during earthquakes.

NON-DISASTER USE

The modules work separately during non-disaster hours as a storage/table unit (mandi/weaving/knitting use).

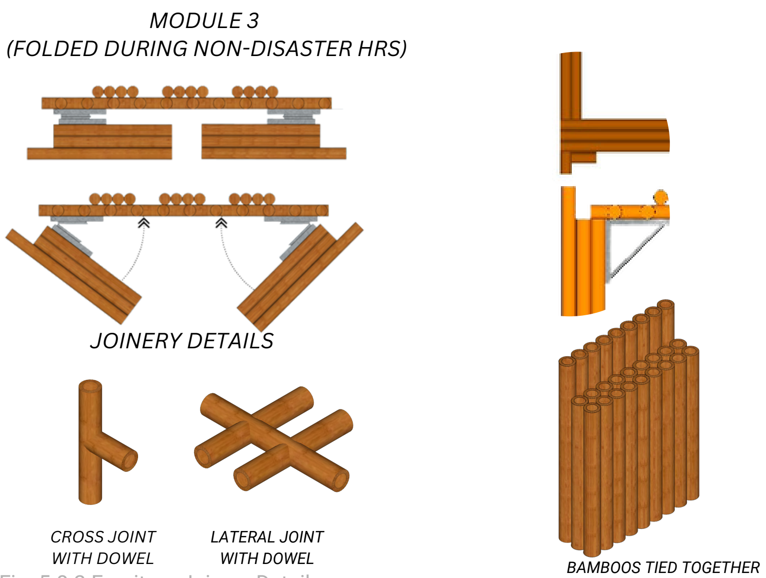
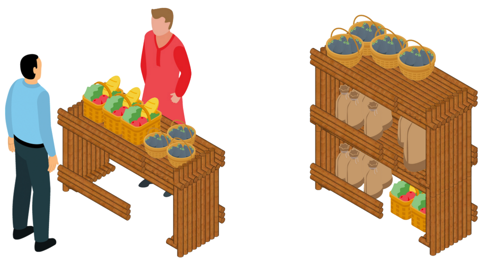


Fig. 5.8.2 Furniture Joinery Details



BAMBOO TYPE USED

Bambusa balcooa

Height: 16-25m   Diametre: 6-15 cm

Curing time: 3 days

Culms are grayish green and thick walled, where the diameter of the cavity is about one-third of that of the culm.

BAMBOO TREATMENT BEFORE USE

Step 1: Heat four liters of water.
Step 2: Add 3.75 cups of Borax and 2.5 cups of Boric Acid to the water. Stir until dissolved.
Step 3: Top off the solution with enough cold water to bring the volume to 10 liters.
Step 4: Soaking the Bamboo. The bamboo should remain in the borax/boric acid solution for about a week, but freshly harvested bamboo doesn't have to be completely immersed.

SCALABILITY & MARKET POTENTIAL

MATERIAL	COST	PRODUCT PRICE
Bamboo + Metal Bracket	4500	-
Jute Mattress (3)	500 per unit 1500	-
	6000	6500

Table 5.9 Scalability & Market Potential

TARGET MARKET

- Customers in rural segments limited by confined space.
- Customers with budget constraints
- Customers who run hostels/dorms which also can flexibly operate as communal spaces

INNOVATION 2

CYCLONE-RESISTANT LOUVERS

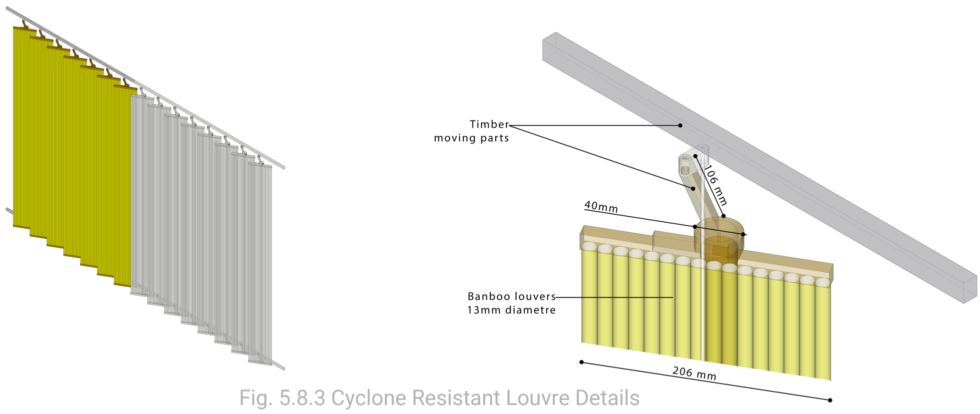


Fig. 5.8.3 Cyclone Resistant Louvre Details

PROBLEM

High winds during disasters can break through and cause major disturbance and damage inside the building. Ventilation is also needed during non-disaster days.

OPPORTUNITY

Adjustable louvers which can collapse or open up as and when needed. The louvers can also manually adjust the lighting and solar radiation levels inside the building, and help improve indoor thermal comfort.

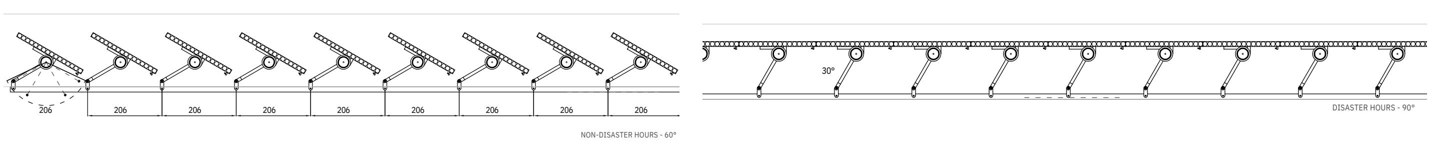


Fig. 5.8.4 Working of Cyclone Resistant Louvres

DISASTER USE

During disaster hours these bamboo louvers can fold parallel to each other in a straight line, forming a strong barrier against incoming cyclonic winds.

NON-DISASTER USE

During non-disaster hours the bamboo louvers will be folded and adjusted at an angle as shown above, to admit natural ventilation and daylight necessary for user comfort. (Refer CFD on page 9)

MATERIAL	COST (per sqm)	PRODUCT PRICE (per sqm)
Bamboo+Timber	4200	4600

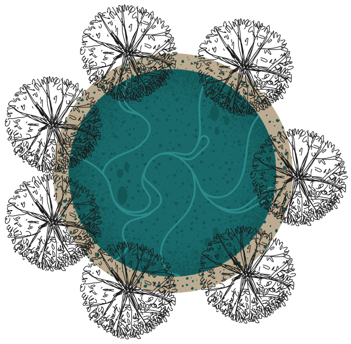
Table 5.10 Costing of Bamboo items

TARGET MARKET

- Customers in similar regions (coastal areas of India which experience monsoon related high velocity winds).
- Can be used for dual purposes in a building. During normal hours it can be used as an excellent mode of cross-ventilation in the building and during harsh conditions, it can close off the structure and provide structural stability and protect the interiors.

INNOVATION 3

MANGROVE PLANTATION SCHEME TO PROTECT COASTAL COMMUNITIES



PROBLEM

Surrounding wetlands have been depleted due to an increase in farming activities. This has made the area around the site more susceptible to flash floods and local communities more vulnerable.

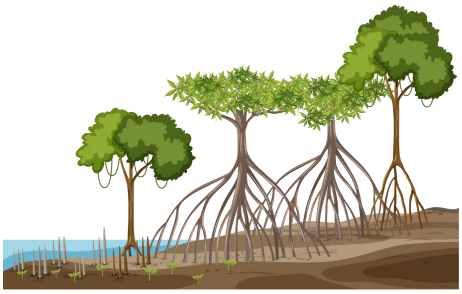
OPPORTUNITY

Capitalize on the surrounding mangrove (which hold the soil together tightly) species to increase the water percolation around the existing wetlands and mitigate the negative impacts of floods.

IMPLEMENTATION

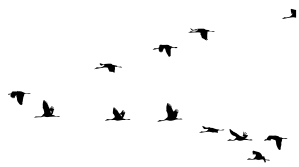
Mangroves species planted: Avicennia
Height of plantation: 3-14 m tall
Time duration for complete growth: 1 year

BENEFITS

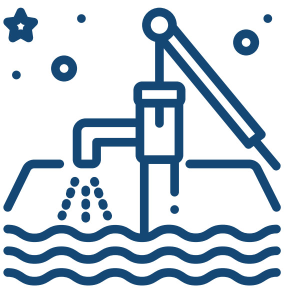


Natural barrier from flood and reduces soil erosion

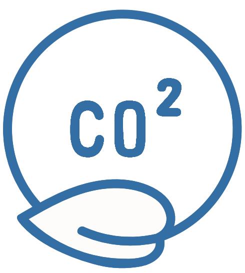
Effective natural barrier against flooding



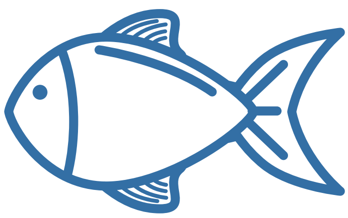
Increase in fauna and migratory birds in the area



Restoration of Groundwater



Carbon absorbtion

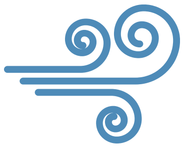


Provides spawning and nursey ground for juvenile marine species

Indoor Environmental Quality

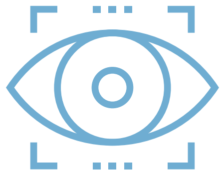
We have followed the ISHRAE standards for Indoor Environmental Quality (IEQ). This standard covers:

Thermal Comfort



Indoor Air Quality

Acoustic Comfort



Visual Comfort

- Maintain Temperature between **24°C and 28°C** through most of the year
- Maintain Relative Humidity at **65%** using non-electric dehumidifiers
- Ensure similar ventilation rates **(6 ach)** in both main occupancy spaces and transition spaces to reduce thermal shock.
- Shading required when DBT exceeds 23.8°C

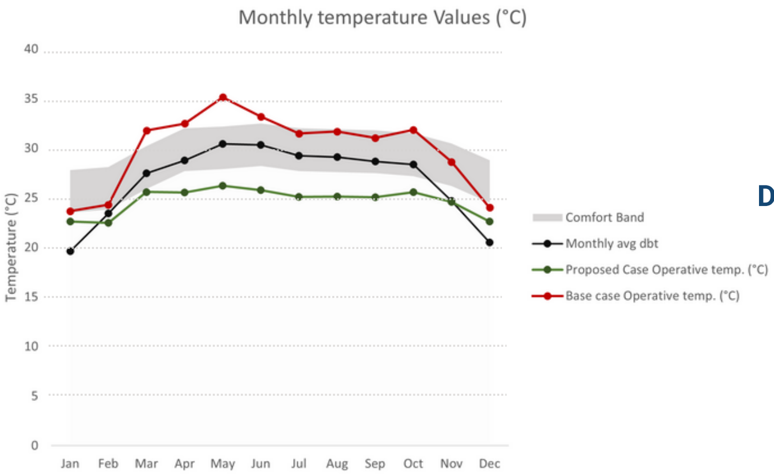


Fig 5.9.1 Monthly Temp, data

During Non Disaster Hours

- Fans running on grid power provide ventilation during non-disaster hours
- Open louvers allow maximum cross ventilation to maintain comfort and RH

During Disaster Hours

- Partially opened louvers allow limited ventilation but, at the same time shield from harsh winds
- Fans running on backup power allow air circulation and ensure thermal comfort.

Comfort parameters

- Fanger PMV ---------- **1.02**
- Fanger PPD ---------- **31.24%**
- Total Discomfort Hours (all clothing) ---------- **2178.43 Hours (24.8%)**

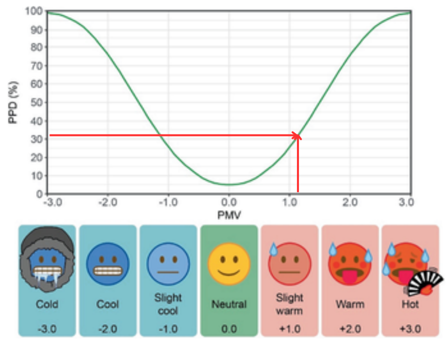
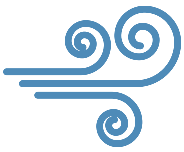
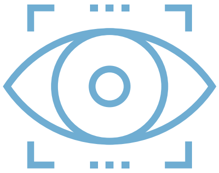


Fig 5.9.2 PMV-PPD



- **Low-VOC** materials have been used to reduce particulates in the air
- The **watertight structure** prevents fungal growth and prevents the spread of disease indoors
- **Ceiling fans and natural ventilation** allows constant air movement and prevents stale air syndrome and other such issues related to air stagnation
- **Plants around the site** reduce the CO_2 content in the air making it "cleaner" to breathe.

- **Trees** placed around the site attenuate sound by approximately **20dB** from the road
- All occupied spaces are **facing away from the primary noise source**, the road.
- The multipurpose hall has **"buffers"** on all sides, except the north to attenuate and block sound from entering the building
- The **kitchen is placed away from the heavily occupied areas** to reduce the noise reaching from there to the occupied areas.

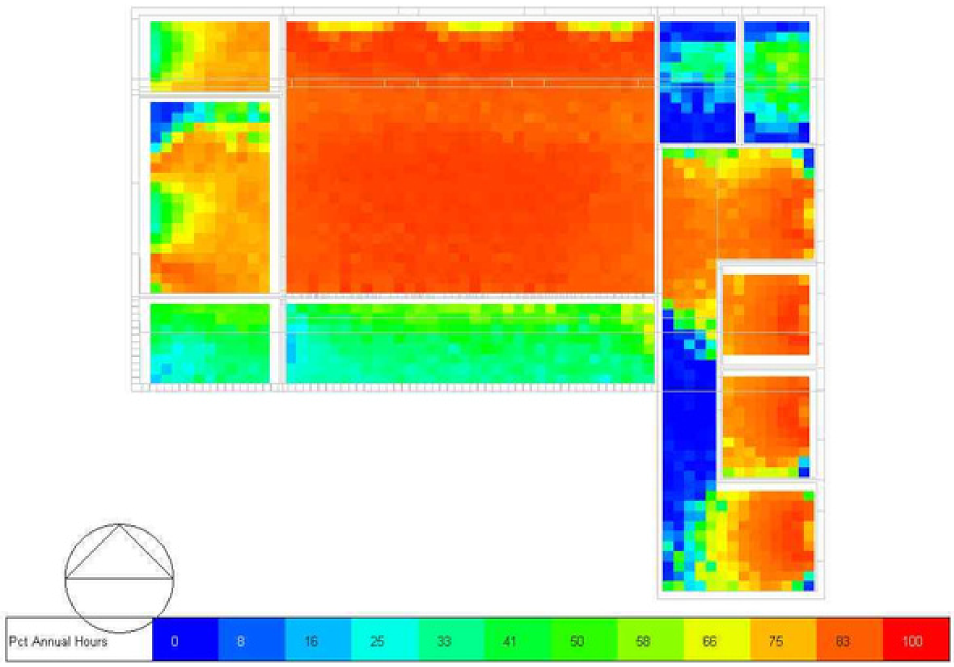


- Surfaces that are of a matte finish and low reflectance to prevent unpleasant and uncomfortable glare
- An average of 205 lux is maintained through daylighting and further supplemented by artificial lighting providing 200 lux during night hours.
- The perforated brick walls create dynamic shadows in the Multipurpose hall and give a pleasant sensation to the users within
- The bulbs provide diffused lighting to prevent further harsh glares
- Clerestories are provided to allow maximum daylighting to create a pleasant light during daytime and also reduce reliance on artificial lighting during the day.

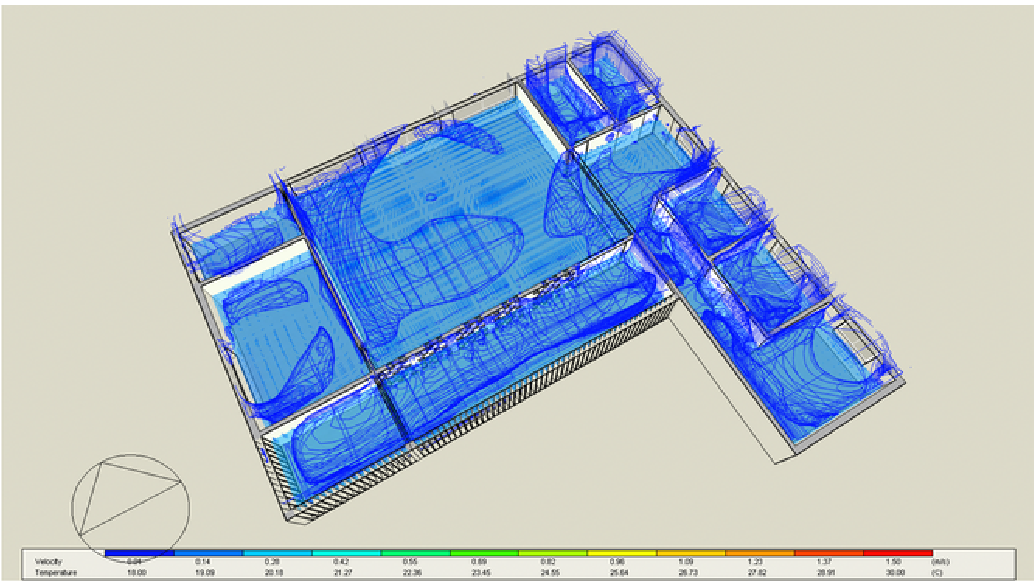
ANTI-GLARE SURFACES

MATTE SURFACE FINISH

DIFFUSED LIGHTING



USEFUL DAYLIGHT ILLUMINANCE



CFD ANALYSIS

SUMMARY OF THE PROJECT

- Reduction of 82.1% in EUI compared to base case
- Providing a self sufficient, resilient shelther
- Reduction of 40% carbon emissions compared to base case
- Reduction of 1.8% costs compared to base case
- Facilitate more people with unique innovation
- Achieved thermal comfort according to ASHRAE standards
- Minimized the wind and cyclone effects
- Achieved net zero water cycle

The site in Gopalnagar is a small town where the community is its strongest asset. The goal of our design is to protect the community as well as promote and grow. It is an area of a high-risk cyclone-prone zone that experiences wind speeds of a maximum of 200 kmph and falls under a Zone IV earthquake-prone area, according to the Indian geological surveys.
Our approach to design is to make sure that all the climatic, comfort and usability requirements are met. We started looking into structure form options and ran them through energy simulations to help understand daylighting, heat gain, efficiency, etc.

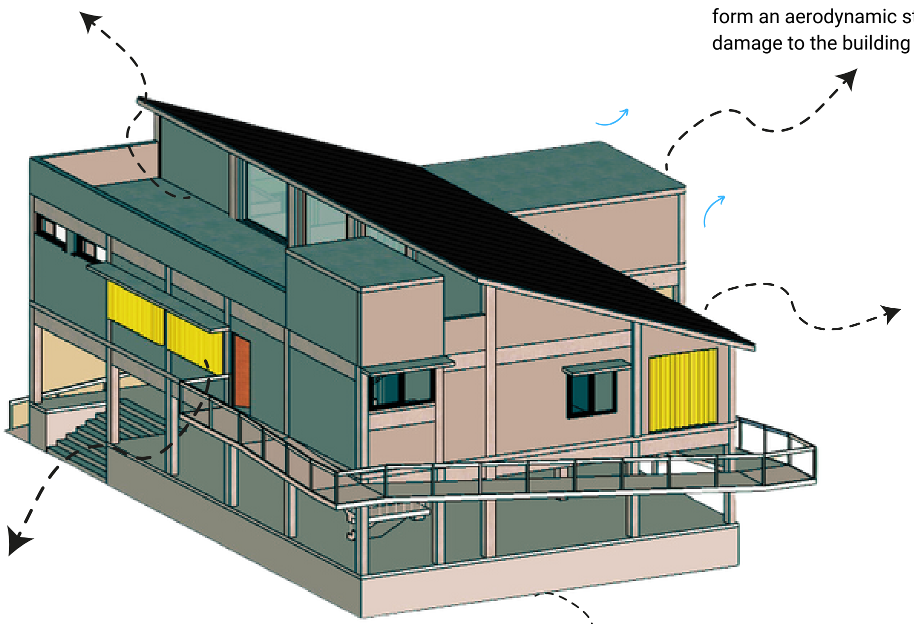


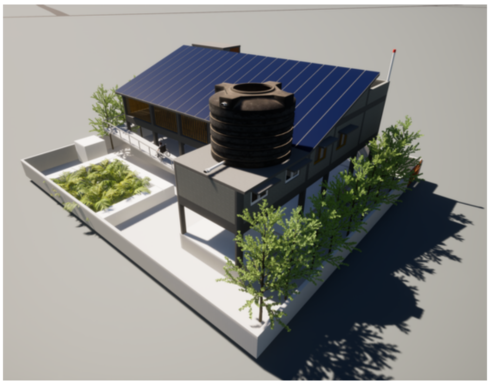
Fig 5.10.1 3D Model with strategies

MARKET POTENTIAL- A PITCH TO THE PROJECT PARTNER

The project aimed to prepare a net zero energy building, focusing on the same, we've designed a multipurpose Community Resilience Shelter that acts as a mandi, weaving center, and a learning space when a disaster is not around the corner.

SEEDs is involved with numerous projects related to both education and Resilience shelters. Our solution provides the opportunity for the optimal usage of land and resources with this multipurpose resilience shelter. Its result of being a Net zero building is an added benefit. This is essential, especially for the end user, as they have to bear the cost of operation and maintenance. This provides SEEDs with a very compelling product to the people and administrators.

- The shelter can be used as a mandi in the stilt area, which acts as a space for cattle/animals during the disaster.
- Also, the main ground floor area can be used as a space for weaving which can be carried out on our innovative furniture system.
- NDMA(or any other organization can utilize the multipurpose space to provide awareness programs for the children from the adjoining school and the community
- There is a room designated for the location of the computer used during disaster times that can be used to educate the children from the adjoining school.
- We've also considered the gender and community conflicts, keeping which in mind the bed units are separated by a collapsible wall.
- The main benefit of the project lies in the fact that it is an adaptable prototype that can be used anywhere with similar conditions that have been considered for this project



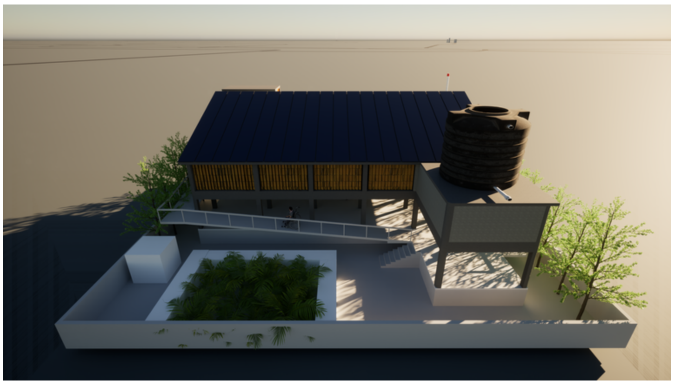
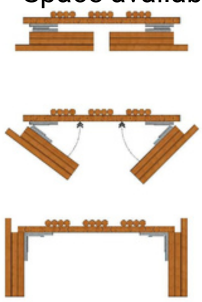


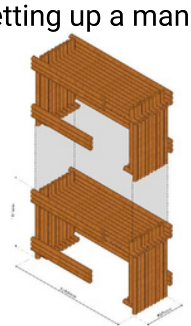
Fig 5.10.2 Exterior Views

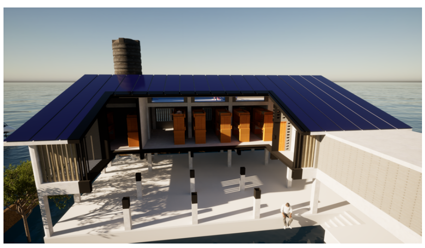
FOR END USERS

We've ensured that the shelter tackles all the problems faced by the locals, which were made aware to us i.e., issues of clean drinking water, shortage of food, and communications.

- Clean drinking water was ensured by making the shelter 100% self-reliant with charcoal filters.
- Communication was made possible by satellite devices.
- A fully equipped kitchen with all the equipment necessary and storage for disaster times
- A creative solution to the space shortage by introducing a three-tier bed system as part of our innovation
- Space available for setting up a mandi, weaving and learning







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APPENDIX

7.1 AREA PROGRAMMING

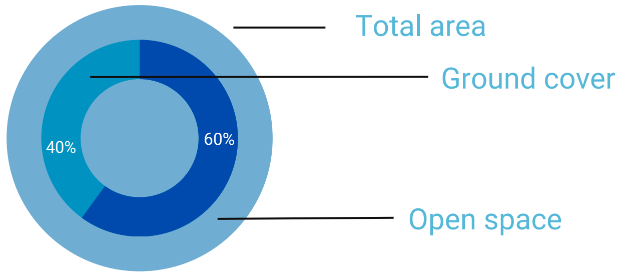


Fig. A Graph of the area split up

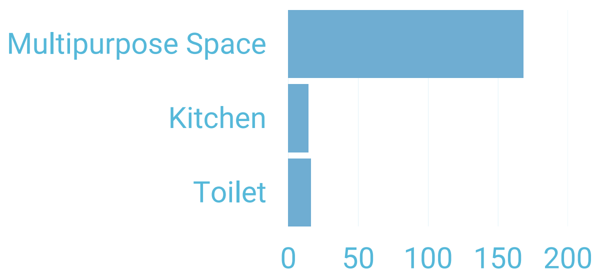


Fig. B Graph showing division of spaces

DURING DISASTER

SR NO.	SPACE	ACTIVITY	NO.OF UNITS	NO.OF USERS	AREA IN SQ.M(per user)	TOTAL AREA IN SQ.M	REMARKS
1.	Multi-Purpose Hall	Dining Area Resting Space Information Desk Medical Consultation	1	45	3.73	160	Area under the MPH (stilt area) shall be used for cattle shelter
2.	Kitchen	Cooking	1	4	0.29	13	
3.	Toilet - Men Women		3	3 2	1.35 1.35	24	Men: 2 urinal + 1 WC Women: 2 WC
4.	Staircase shaft	Vertical circulation		45		8	
	TOTAL AREA + 15% circulation					236	Without circulation: 205 sq.m

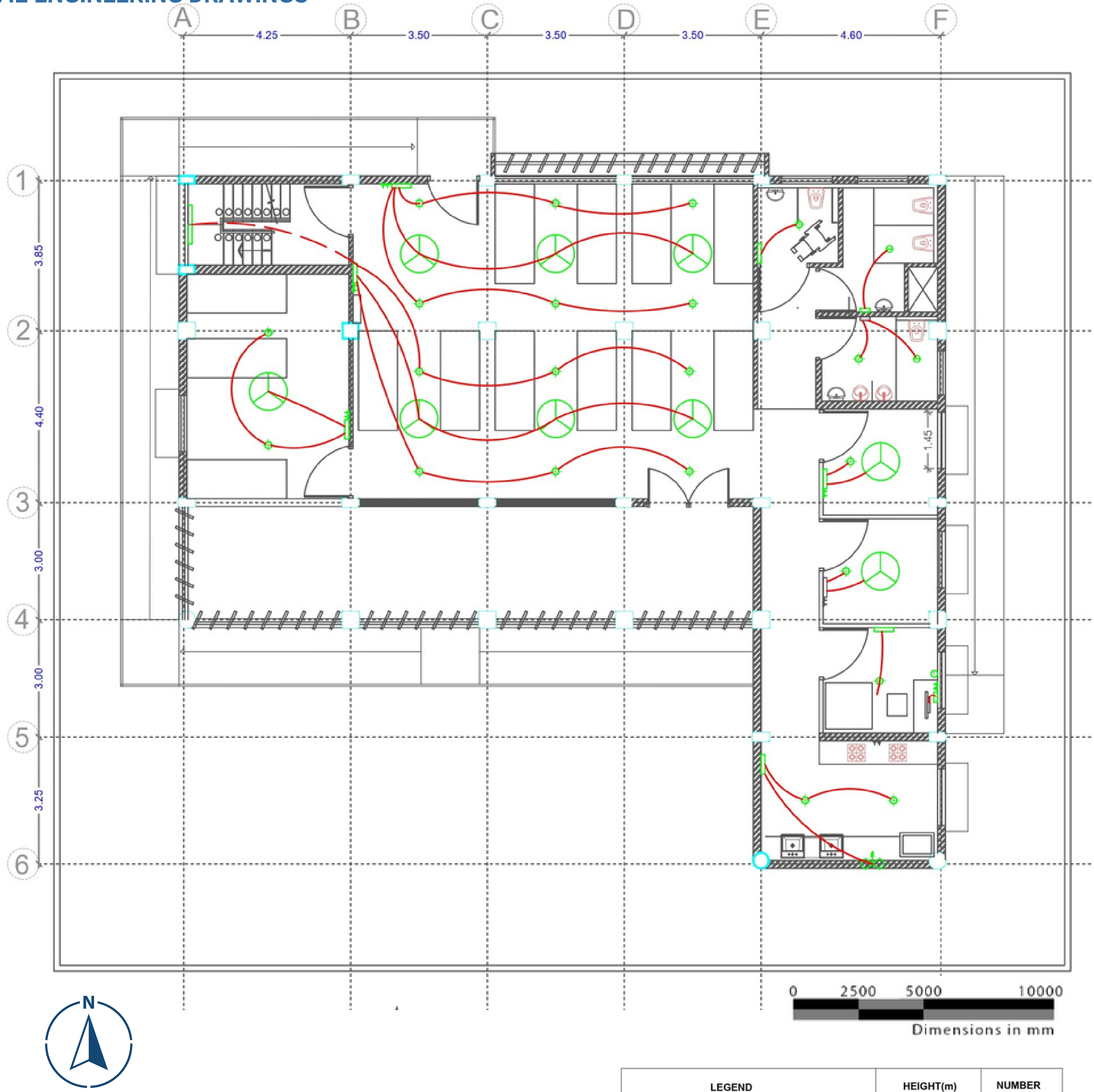
Table 1 Area Programming - During Disaster

DURING NON-DISASTER

SR NO.	SPACE	ACTIVITY	NO.OF UNITS	NO.OF USERS	AREA IN SQ.M (per user)	TOTAL AREA IN SQ.M	REMARKS
1.	Multi-Purpose Hall	Knitting /Weaving Activity Space	1	45+	2.73	115	Area under the MPH (stilt area) shall be used as the mandi area (market) for floating users
2.	Kitchen		1	4	0.29	13	
3.	Isolation room	Recovery room Quarantine room	1	10	1.8	21	
4.	Toilet - Men Women		4 4 2	3 2	1.35 1.353	24 (includes overall W.C area)	Men: 2 urinal + 1 WC Women: 2 WC
5.	Storage Mattress Storage Medical	Same function	1	5	2	7.5 7.5	In-floor storage (MPH area)
6.	Reserve (Agriculture) Pantry storage		1	3	3	9	
7.	Staircase shaft	Same function		45		8	
	TOTAL AREA + 15% circulation					236	Without circulation: 205 sq.m

Table 2 Area Programming - During Non-disaster

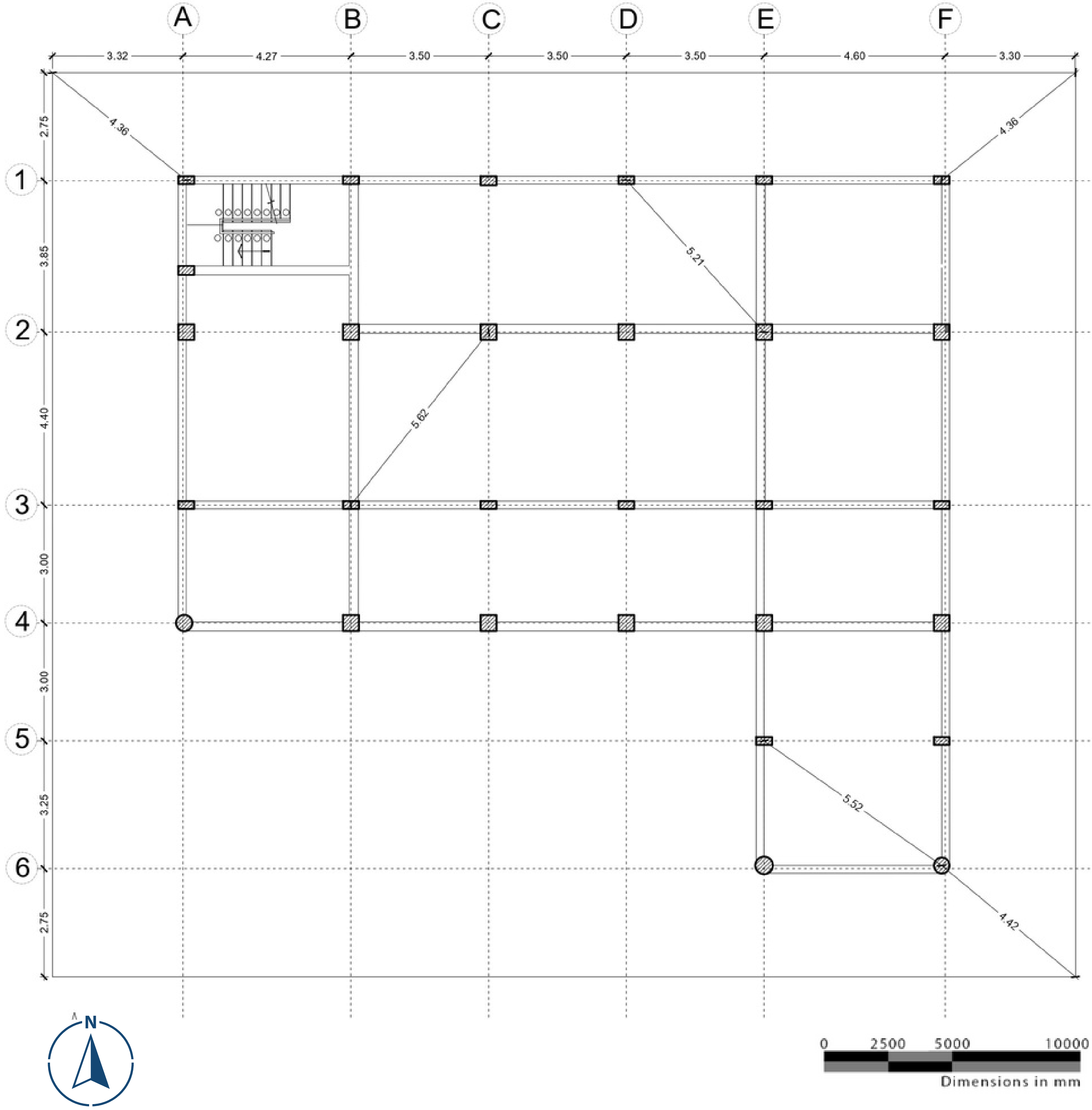
7.2 ENGINEERING DRAWINGS



LEGEND		HEIGHT(m)	NUMBER
	SWITCH POINT	1.2	10
	PLUG POINT(5 Amp)	0.9 (1.35 - KITCHEN AND TOILET)	12
	PLUG POINT(15 Amp)	2.7 (0.9 - KITCHEN, STORAGE)	2
	TELEPHONE POINT	0.6	1
	TUBELIGHT	2.4	1
	ONE-WAY CONNECTION WIRE	-	-
	TWO-WAY CONNECTION WIRE	-	-
	CEILING FAN (RADIUS = 0.75m	3	9
	DISTRIBUTION BOX	1.8	1
	CEILING LIGHT	3	21
	LOW VOLT CEILING LIGHT	3	2

First Floor Electrical Plan

Fig. C First Floor Electrical Plan



Structural Plan

Fig. D Structural Plan

7.3 BASELINE WATER CALCULATIONS

Domestic Use	
Use LPD/Head	135
Number of peop	45
Total LPD	6075

Irrigation Use	
L/m²	1
Area m²	106
Max LPD	106

Table 3 Water Consumption for domestic and irrigation use

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing	30%	1823	1,823	
Washing	20%	1215	1,215	
Cleaning house	8%	486	486	
Washing Utensi	16%	972	972	
Others	2%	122	61	61
Drinking	4%	243		243
Cooking	3%	182		182
Toilet Flushing	17%	1033		1,033
Total		6075	4,556	1,519

Table 4 End uses - Disaster Hours

		CONSUMPTION						WATER SOURCES				
Month	Days in month	Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Bore water (L)	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	1,88,325	90%	-	5%	164	1,88,489	-	89610	1,41,244	47,081	42364
Aug	31	1,88,325	80%	-	5%	164	1,88,489	-	86520	1,41,244	47,081	81639
Sep	30	1,82,250	50%	-	50%	1,590	1,83,840	-	72306	1,36,688	45,563	106792
Oct	31	1,88,325	75%	-	30%	986	1,89,311	-	36153	1,41,244	47,081	94878
Nov	30	1,82,250	20%	-	90%	2,862	1,85,112	-	7725	1,36,688	45,563	54179
Dec	31	1,88,325	0%	-	90%	2,957	1,91,282	-	927	1,41,244	47,081	5067
Jan	31	1,88,325	0%	-	90%	2,957	1,91,282	43,426	1545	1,41,244	47,081	0
Feb	28	1,71,619	20%	-	90%	2,695	1,74,314	40,965	4635	1,28,714	42,905	0
Mar	31	1,88,325	50%	-	90%	2,957	1,91,282	43,859	6180	1,41,244	47,081	0
Apr	30	1,82,250	90%	-	90%	2,862	1,85,112	35,755	12669	1,36,688	45,563	0
May	31	1,88,325	100%	-	90%	2,957	1,91,282	18,521	31518	1,41,244	47,081	0
Jun	30	1,82,250	90%	-	90%	2,862	1,85,112	-	72306	1,36,688	45,563	23882
Total							22,44,909	1,82,526	4,22,094	16,64,170		(1,58,644)

Table 5 Water Balance - Disaster Hours

End Use	Percent use	Use in LPD	Greywater in LPD	Blackwater in LPD
Bathing		0	-	
Washing		0	-	
Cleaning house	8%	486	486	
Washing Utensils	16%	972	972	
Others	2%	122	61	61
Drinking	30%	1823		1,823
Cooking	14%	851		851
Toilet Flushing	30%	1823		1,823
Total		6075	1,519	4,556

Table 6 End uses - Non-Disaster Hours

	Days in month	CONSUMPTION						WATER SOURCES				
Month		Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Bore Water (L)	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	1,88,325	90%	-	5%	164	1,88,489	51,798	89610	47,081	1,41,244	0
Aug	31	1,88,325	80%	-	5%	164	1,88,489	54,888	86520	47,081	1,41,244	0
Sep	30	1,82,250	50%	-	50%	1,590	1,83,840	65,972	72306	45,563	1,36,688	0
Oct	31	1,88,325	75%	-	30%	986	1,89,311	1,06,076	36153	47,081	1,41,244	0
Nov	30	1,82,250	20%	-	90%	2,862	1,85,112	1,31,825	7725	45,563	1,36,688	0
Dec	31	1,88,325	0%	-	90%	2,957	1,91,282	1,43,274	927	47,081	1,41,244	0
Jan	31	1,88,325	0%	-	90%	2,957	1,91,282	1,42,656	1545	47,081	1,41,244	0
Feb	28	1,71,619	20%	-	90%	2,695	1,74,314	1,26,774	4635	42,905	1,28,714	0
Mar	31	1,88,325	50%	-	90%	2,957	1,91,282	1,38,021	6180	47,081	1,41,244	0
Apr	30	1,82,250	90%	-	90%	2,862	1,85,112	1,26,881	12669	45,563	1,36,688	0
May	31	1,88,325	100%	-	90%	2,957	1,91,282	1,12,683	31518	47,081	1,41,244	0
Jun	30	1,82,250	90%	-	90%	2,862	1,85,112	67,243	72306	45,563	1,36,688	0
Total							22,44,909	12,68,091	4,22,094	5,54,723		(12,68,091)

Table 7 Water Balance - Non-Disaster Hours

7.4 OUTLINE SPECIFICATIONS

BASE CASE (AS PER ECBC STANDARDS)			PROPOSED CASE		
ITEM	**DESCRIPTION**	**MEASURE LEVELS**	**ITEM**	**DESCRIPTION**	**MEASURE LEVELS**
WALL			**WALL**		
Brick Wall + Cement Plaster(for outer structure)	200mm + Cement plaster (15mm)	U value = 2.23(W/m2-k)	Agrocrete Hollow block + Cement Plaster	200mm + 15mm Cement plaster on interior and exterior faces.	U value = 1.097 (W/m2-k)
Brick Wall(for indoor divisions)	100mm thickness	U value = 1.63(W/m2-k)	Borax treated bamboo	95mm Diameter	U value = 1.538(W/m2-k)
ROOF			**ROOF**		
RCC Slab	150 mm thickness	U value = 5.0(W/m2-k)	RCC Slab + Waterproofing	150mm +15mm water proofing	U value = 4(W/m2-k)
WINDOWS			**WINDOWS**		
Window Glazing	Single Glazing 6mm clear glass	U value = 5.778(W/m2-k)	Window Glazing	Double Glazing, 6mm FRP	U value = 1.685(W/m2-k)
		SHGC=0.819			SHGC=0.36
		VLT=0.881			VLT = 0.602
PLUMBING SYSTEM			**PLUMBING SYSTEM**		
Wash Basin/Faucet	Regular flow fixture	10L per min	Wash Basin/Faucet	Water Efficient low flow fixture based faucet	Control flow rate due to efficient low flow restrictors
					Water savings upto 60% to 80% (1.8 L in 12 seconds)
					5.6L Per minute
Water closet	Regular Flush System	10 L per flush	Water closet	Dual Flush Systems	Dual flush 4/2L WC cistern with bottom inlet for compact back to wall rimless toilet
					Cistern dimensions: LXWXH; (365X150X405)mm

Table 8 - OUTLINE SPECIFICATIONS - 1

7.4 OUTLINE SPECIFICATIONS

BASE DESIGN VALUES (ECBC STANDARDS)			PROPOSED DESIGN VALUES		
ITEM	**DESCRIPTION**	**MEASURE LEVELS**	**ITEM**	**DESCRIPTION**	**MEASURE LEVELS**
LIGHTING FIXTURES			**LIGHTING FIXTURES**		
Fluorescent Bulb	BEE Rating	3-Star	LED Bulbs	BEE Rating	5-Star
	Wattage	14W		Wattage	10W
	Rated I/P Voltage	240V		Rated I/P Voltage	240V
	Lamp Life	6000 Hrs.		Lamp Life	15000 Hrs.
	Rated Efficacy	80 lm/W		Rated Efficacy	120 lm/W
	Wattage Equivalent	75W		Wattage Equivalent	
FANS			**FANS**		
1-Star Fan	BEE Rating	1-Star	3-Star Fan	BEE Rating	3-Star
	Wattage	55W		Wattage	40W
	Sweep Size	1200 mm		Sweep Size	1200 mm
	Rated Speed	390 rpm		Rated Speed	350 rpm
REFRIGERATORS			**REFRIGERATORS**		
Single Door, 250 L	BEE Rating	3-Star	Single Door, 250 L	BEE Rating	5-Star
	Wattage	253W		Wattage	68W
	Compressor	Linear Cooling		Compressor	Normal
	Voltage	230V		Voltage	230V
SOLAR PV			**SOLAR PV**		
None	None		Rooftop Solar PV	Type	Mono PERC module, 15 cell
				Capacity	5kW
BATTERY			**BATTERY**		
None	None		Lead Acid	Amperage	500A
				Voltage	12V
PUMPS			**PUMPS**		
Submersible	Phase	Single Phase	Submersible	Phase	Single Phase
	Power	2 HP		Power	1.5 HP
	Operation Voltage	230V		Operation Voltage	230V
	Wattage	2555 W		Wattage	1490 W
	Weight	23kg		Weight	23kg
Centrifugal	Phase	Single Phase	Centrifugal	Phase	Single Phase
	Power	1 HP		Power	1 HP
	Operation Voltage	230V		Operation Voltage	230V
	Weight	10kg		Weight	10kg
	Wattage	1200 W		Wattage	745 W

Table 9 - OUTLINE SPECIFICATIONS - 2

7.5 INPUT AND OUTPUT PARAMETERS

Input & Output Parameters		
Input Parameters	**Units**	**Proposed Design Values**
General		
Building Area	m^2	236
Conditioned Area	m^2	0
Electricity Rate	INR/kWh	6.93
Natural gas Rate	INR/GJ	817.67
Building Occupancy Hours	Hours	8
Average Occupany density	m^2/Person	5.24
Internal Loads		
Interior Average LPD	W/m^2	1.398
List of Lighting controls	None	None
Average Equipment PD	W/m^2	14.67
Envelope		
Roof assembly U Vlaue	W/m^2.K	4
Roof Assembly SRI	None	70
Average Wall assembly U value	W/m^2.K	1.097
Window to Wall Ratio (WWR)	%	30
Windows U Value	W/m^2.K	1.685
Windows SHGC	None	0.36
Windows VLT	%	0.602
Infiltration Rate	ac/h	0.7
Exterior Shading Device Details	None	0.6m Overhang
Service Hot Water		
Type and Description	None	Instaneous Water Heater Delivery Temp. = 65°C DHW COP = 1
Output Parameters	**Units**	**Proposed Design Values**
Proposed EUI (Total)	kWh/m^2/yr	11.83
EUI breakdown By End Use		
Fans	kWh/m^2/yr	1.484
Pumps	kWh/m^2/yr	2.3
Lighting	kWh/m^2/yr	0.136
Equipment	kWh/m^2/yr	0.28
Total Envelope Heat Gain (Peak)	W/m^2	-43.11
Building Electric (Peak)	W/m^2	24.52
Annual Operating Energy Cost	INR/m^2	77.23
Annual Unmet Hours	Hours	2178.43
Annual Hours of Comfort Without AC	Hours	6581.57

Table 10 - INPUT AND OUTPUT PARAMETERS

SEEDS

15-a institutional area, r.k. puram, sector IV, new delhi - 110022, india
tel.: (91-11) 26174272, telefax (91-11) 26174572

SEEDS/Mentoring/01/2022 Date: 08.09.2022

To,

The Director,
Solar Decathlon India

Greetings from SEEDS!

Dear Sir,

This is to inform you that our organization **SEEDS (Sustainable Environment and Ecological Development Society)** has provided information about our **Gopal Nagar Flood Relief Shelter, West Bengal** project to the participating team led by the **Manipal School of Architecture and Planning**, so that their team **Team Tattva** 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 be mentoring team Tattva and 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,

Varghese Antony

Digitally signed by Varghese Antony
DN: cn=Varghese Antony, o=SEEDS, ou, email=varghese@seedsindia.org, c=US
Date: 2022.09.15 10:12:33 +05'30'

Name of Representative: Varghese Antony
Designation: Chief Operating Officer
Email: varghese@seedsindia.org
Phone: 9818571848

Address

GreenJams BuildTech Pvt. Ltd.,

401, 10-5-14/c, Mantis,
Facor Layout, Ramnagar,
Visakhapatnam – 530 002

10.02.2023

To,
The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organisation GreenJams is collaborating with team TATTVA led by Manipal School of Architecture and Planning on a Community Resilience Shelter project for their Solar Decathlon India 2022-2023 competition entry.

The nature of our collaboration will be to mentor the team on carbon mitigation strategies and provide information about the product offerings at GreenJams.

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

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

With warm regards,

Tarun Jami,
Founder & CEO
GreenJams
tarun@greenjams.org
+919591170791