VANSHAH SAHAYA

TEAM TEJASVI
COMMUNITY RESILIENCE SHELTER

FINAL DESIGN REPORT
APRIL 2022

INDIAN INSTITUTE OF TECHNOLOGY, ROPAR (LEAD INSTITUTE),
MBS SCHOOL OF PLANNING AND ARCHITECTURE,
SARDAR PATEL COLLEGE OF ENGINEERING, MUMBAI,
IUST KASHMIR, NIT SRINAGAR, BANASTHALI VIDYAPITH

Project Partner-SEEDS

Team Tejasvi

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EXECUTIVE SUMMARY

“Vanshah Sahaya” is a vision of a vibrant team of future energy-efficient building architects, scientists and engineers from six different academic institutions united by their resolve to implement sustainable development goals for assisting economically disadvantaged communities in disasters.

In partnership with SEEDS India, a community resilient shelter has been designed for Golaghat (Assam) in a seismic and flood-prone zone. The design shelter incorporates novel engineering features like implementing algorithms to track solar energy, battery management and storage grids, use of PERC solar panels, conceptualizing an earthquake-resistant building through the use of bracing and performing seismic checks using local materials, exploring the use of zerund bricks.

The architecture of “Vanshah Sahaya” emphasizes the importance of students developing solutions for communities, where budgets are stringent and a multi-use structure needs to be evolved. The conceptualization began from the perspective of a disaster-prone person particularly helping women with infants, need of helping displaced people with e-governance and cattle, and extends to fusing design elements like pile foundations, fenestrations (jaalis) to maximize natural ventilation, square design, wet floodproofing to provide a safe space.

The future steps envisaged by Team Tejasvi include discussing the solution developed with SEEDS India; and sharing the findings with various government agencies like Assam Energy Development Agency and non-governmental agencies like the United Nations High Commissioner for Refugees, Engineers without Borders.

The team is grateful to SEEDS India and Solar Decathlon India for the opportunity to open up new vistas in learning particularly with constraints associated with materials innovation in low-cost materials like Bamboo, management of floodwater reuse in disaster situations, use of an appropriate roof (gable vs. thatched) in economically constrained scenarios. The participating students look forward to extending their learning in developing the community resilience shelter through internships, social entrepreneurship challenges and working with organizations contributing in the area of bridging climate change and building science.

TEJASVI IIT ROPAR

COMMUNITY RESILIENCE SHELTER
TEAM STRUCTURE

Mehak Gupta (Team Lead):
Architect (UG, 3rd year), MBS SPA

Resilience Lead
Prabhjot, Civil Engineer
4th Year UG, IIT ROPAR

Affordability Lead
Vishal, Architect
3rd Year UG, MBS SPA

Water Performance Lead
Sukriti, Chemical Engineer
3rd Year UG,Banasthali Vidyapith

Communications Lead
Satanshu, Civil Engineer
3rd Year UG, IIT ROPAR

Health and Well Being Lead
Swarnahiya, Architect
3rd Year UG, MBS SPA

Khubaan
Chemical Engineer
3rd Year UG, NIT Srinagar

Architectural Design Lead
Arjun, Architect
3rd Year UG, MBS SPA

Energy Performance Lead
Vedant, Electrical Engineer
2nd Year UG, IIT ROPAR

Engineering Design &Operations Lead
Mahshida, Mechanical Engineer
4th Year UG, IUST Kashmir

Sartaj
Chemical Engineer
3rd Year UG, NIT Srinagar

Scalability & Market Potential Lead
Shruti, Civil Engineer,
Sardar Patel College Of Eng.

Himanshu
Mechanical Engineer
2nd Year UG, IIT ROPAR

Kanha, Civil Engineer
3rd Year UG, IIT ROPAR

ABOUT FACULTY LEAD

Dr. Asad Sahir is Head-Professional Development, CDCRC, and Assistant Professor-Chemical Engineering at IIT Ropar. His previous association with NREL (USDoE Lab, Golden, CO) inspired him to support the team. He earned his Ph.D. from the University of Utah.

APPROACH

The team comprises students from six disciplines and six institutions working together. Based on the previous year's success we have four architects (from MBS SPA New Delhi), backed up by a team of civil engineers (from IIT Ropar and Sardar Patel College), Chemical Engineers (from Banasthali Vidyapith, NIT Srinagar), Mechanical Engineer (from IUST Pulwama), electrical engineer and metallurgical engineer (from IIT Ropar). Our approach is to form a team of enthusiastic students from different fields and cooperate toward building a net-zero modular community resilient shelter using local materials with synergistic communication between engineers and architects. A leader is appointed for each of the ten contests to address them to the best possible extent. Also, meetings with project partner SEEDS are conducted to update them about the progress and take feedback as we move forward.

BACKGROUND OF IIT ROPAR

Indian Institute of Technology, Ropar is one of the eight "new generation" IITs set up by the Ministry of Human Resource Development (MHRD). IIT Ropar has evolved a culture of fostering collaborations among students from various institutions. The courses offered by the institution as a curriculum provide a high yielding practical knowledge to the students viz. 'Human Geography and societal needs', 'Material Engineering', 'Water Resources Engineering' along with essential courses like, 'Geomatics' and 'Environmental sciences'.

ACKNOWLEDGMENTS

Team Tejasvi IIT Ropar is grateful to SEEDS India (Ms. Toniya Elizabeth, Mr. Manu Gupta, Mr. Sumeet, Ms. Shruti) and Mr. Parwez Yusuf for a review of the design. From IIT Ropar, the student team appreciates Dr. Muthulingam Subramaniyan for insights on resilience, Ar. Arpita Agarwal , MBS-SPA, and Mr. Abhimanyu Dhariwal, TRG SDI.

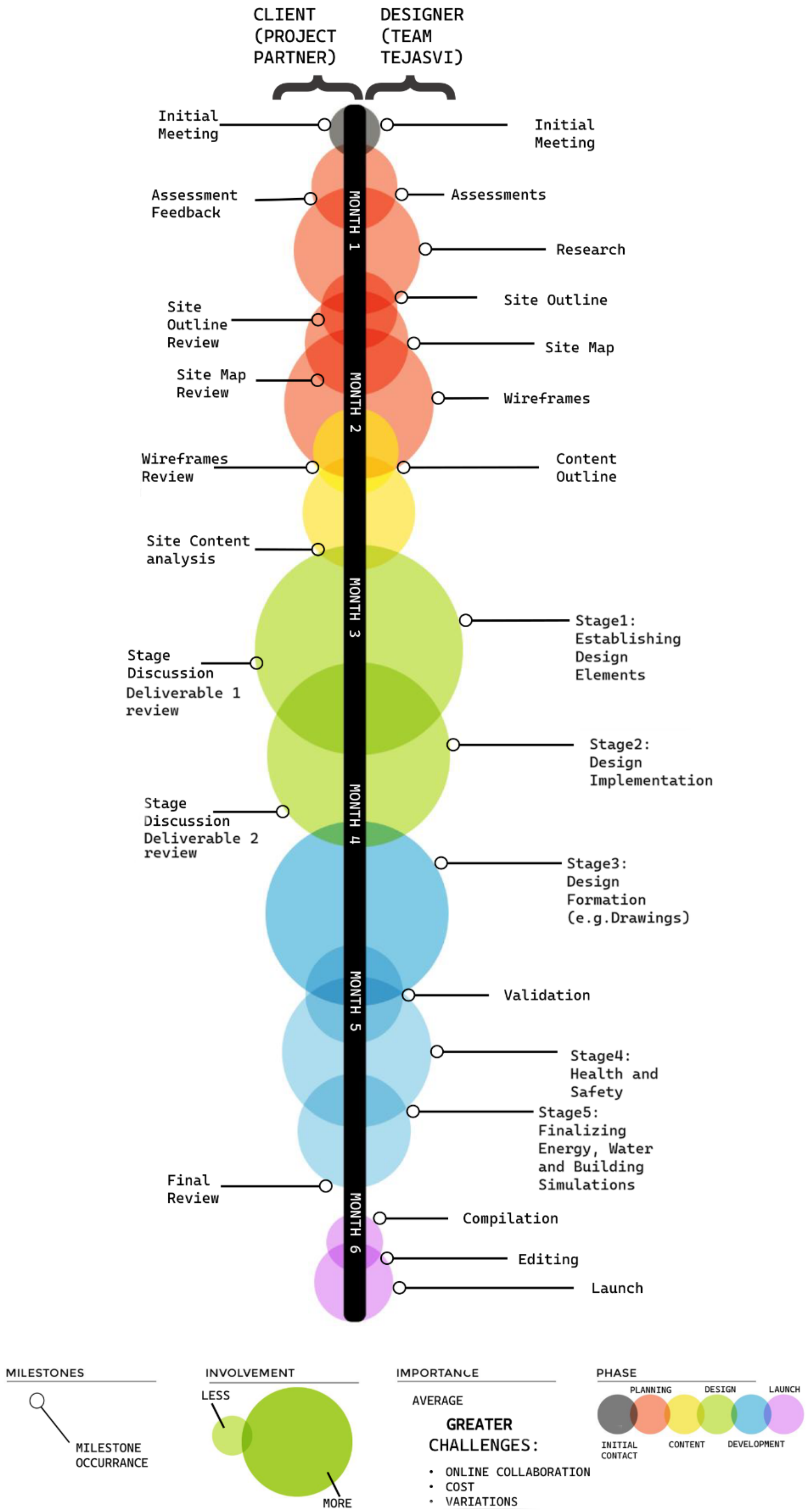


Fig 1. Design Charrette

TEAM MEETINGS

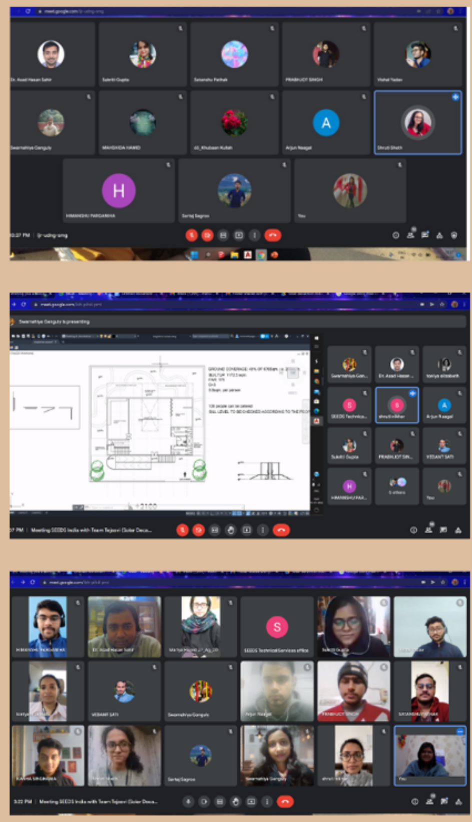


Fig 2.Meetings with Project Partner

TOOLS USED

PROJECT BACKGROUND

A. PROJECT NAME: Vanshah Sahaya
(*"Vanshah"* is a Sanskrit word for grass family to which bamboo belongs and *"Sahaya"* means to help and also in reverence to Lord Shiva.)

B. PROJECT PARTNER: SEEDS (Sustainable Environment and Ecological Development Society) is a non-profit voluntary organization founded in 1994. It has one ultimate goal: "*building resilience shelters for people exposed to disasters, and building practical solutions for disaster readiness, response, rehabilitation, and management"*. Team Tejasvi has had the opportunity and privilege to have multiple meetings with Ms. Toniya Elizabeth, Architect (Sustainability) which has increased the quality of our contribution significantly.

C. PROJECT DESCRIPTION:

1. Location: SEEDS has identified Nikori village in Assam under Disoi Gram Panchayat to build the flood shelter. It is located in Borpak, West block 'Bokakhat' of Golaghat district.

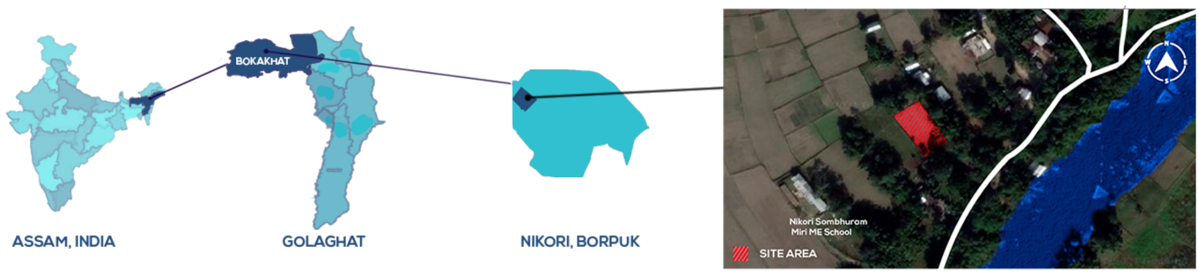


Fig 3. Latitude : 26°41'19.5"N, Longitude : 93°44'05.2"E; Site (Google Maps)

2. Climate Zone: Golaghat region has a warm and humid climate type. This region experiences warm and humid summers with cold and dry winters. Golaghat falls within the temperate region with monsoon-type rainfall prevailing throughout the year.

3. Project Stage: Final Stage

4. Profile of occupants: Local people of Nikori, Golaghat, and nearby villages

5. Hours of operation: 24*7

D. BUILT-UP AREA: 817 m^2 (considering the maximum FAR=175 and maximum Ground coverage=45% as per Assam notified urban areas other than Guwahati building rules 2014, pg.56)

E. TARGET EPI: The desired range of EPI for community resilience shelter is from 54 kWh/m^2/year- 65 kWh/m^2/year with the lower bound of 54 kWh/m^2/year is very difficult to achieve. Thus our team has achieved the EPI value of 59 kWh/m^2/year.

F. ON-SITE RENEWABLE ENERGY GENERATION: Incident solar energy and rainfall occurring in the region to produce opportunities for the generation of non-renewable energy.

The Golaghat receives solar irradiance above 600 W/m^2 during solar noon, except in January and December. Golaghat being a paddy and a tea-growing region, deployment of a Solar Photovoltaic system in Golaghat has significant potential as per literature during the working season.1

Apart from this, the Assam Energy Development Agency has started up a 14 MW GRID CONNECTED SOLAR ROOFTOP PROGRAMME in the state whose objectives are to promote the grid-connected Solar Photovoltaic rooftop power generating plants among the residential, community, institutional, industrial, and commercial establishments. The design provided by Tejasvi 2.0 will be useful to further the conversation with Assam Energy Development Agency

G. BUDGET: Approximate budget (excluding land area cost)- The construction cost should not be more than Rs. 1,400 per sq.ft. or Rs. 15,070 per m^2 as provided by the project partner. Therefore, the preliminary construction budget cap is estimated to be Rs. 1.01 crore.

PERFORMANCE SPECIFICATION

WATER SYSTEMS

The water system design aims to reduce everyday consumption by 30% using water-efficient fixtures like aerators. Furthermore, the design also helps in restricting the backflow of water, by using inline check valves.

Components	Capacity	Nature/Significance
Underground Storage Tank	50 kL ($50m^3$)	Serves as the main source of freshwater demand, with water intake mainly from municipality supply and aided by harvested rainwater overflow (from overhead water tanks). Designed to prevent flood contamination.
Overhead tanks	3 tanks of 15 kL ($5m^3$ each) are provided to support smooth water flow	Rainwater is fed directly to these tanks and the only overflow goes to the underground storage tank, to reduce the pumping power and to use the pump only once a day.
Greywater Treatment system	Approx 630 kL annually (Sufficient to meet everyday flushing demands.)	The use of multi-grade and activated carbon filter beds leads to on-site cost-effective treatment. The treatment system has an efficiency of 75% which was enhanced by disinfectants. Primary Treatment is done underground so as to pump greywater, for Secondary & Tertiary treatment, to the rooftop without any solid impurity.
Rainwater Treatment	Approx 500 kL annually	The water filters provide more than 90% efficiency and help to remove debris from rainwater. Disinfectant tablets are used to enhance water quality.

Table 1. Water Systems Capacity

ENERGY SYSTEMS AND ENGINEERING DESIGN

Solar Panel Specification

- Type of Solar panels used:- 330 Watts PERC solar panels used.
- Number of solar panels used - 30
- Efficiency of each PERC solar panel - 18%
- Daylight (hours) - 6 hours
- Total Energy on average produced daily - 8.9 kWh
- Solar Control Used - MPPT (Maximum Power Point Tracking)
- MPPT Algorithm used - Incremental conductance.
- Energy Grid used - FLOW battery storage.
- Size of the battery system - 27 kWh.
- Battery backup that can be provided - 32-36 hours.

Room	Area	Appliance-Quantity-Specifications
Toilet - 5	10 sqm	LED bulb - 1 - 1200 Lumens/9 Watts, Exhaust Fan - 1 - 32 Watts
Bathroom-4	6 sqm	LED bulb - 1 - 800 Lumens/7 Watts
Medical Room - 1	20 sqm	LED bulb - 1 - 5000 Lumens/42 Watts , LED bulb - 1 - 100 Lumens / 5 Watts, Fan - 1 - 35 Watts
Storage Room - 1	28 sqm	LED bulb -1- 5000 Lumens/42 Watts
Kitchen - 1	50 sqm	LED bulb -2- 5000 Lumens/42 Watts , LED bulb -1-400 Lumens / 7 Watts ,Exhaust Fan - 1 - 32 Watts, Refrigerator - 1-180L
Male Dormitory -1	55 sqm	LED bulb -2- 5000 Lumens/42 Watts, LED bulb -1-400 Lumens / 7 Watts , Fan - 2 - 80 Watts
Female Dormitory - 1	55 sqm	LED bulb -2- 5000 Lumens/42 Watts , LED bulb -1-400 Lumens / 7 Watts , Fan - 2 - 80 Watts
IT Area-1, Elec Room - 1 Control Room - 1	20 sqm	LED bulb - 1 - 5000 Lumens/42 Watts , Fan - 1- 35 Watts , Computer - 3 - 210 Watts
Common Area	82 sqm	LED bulb - 4 - 5000 Lumens/ 42 Watts , Fan - 2- 80 Watts

Table 2. . Electrical Equipment Specifications

GOALS

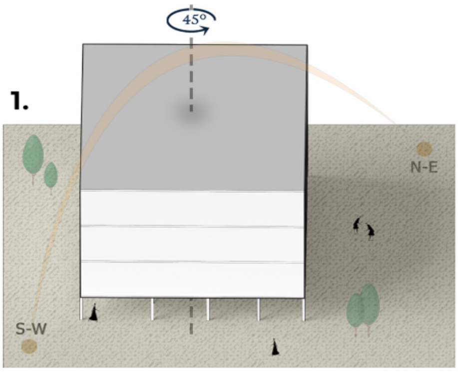
Architecture	• Provides 70-90% lit spaces to enhance the visual connection between indoor and outdoor spaces. • Passive design for natural ventilation. • The Gable roof is inspired by local architecture to bring a feeling of collectivism to our design. • Use of Partition walls instead of Permanent walls to make the spaces modular and to reduce construction costs and increase adaptability. • Bamboo and jute walls were chosen to achieve effective cost and sustainability reducing construction time. • Provision for cattle shelter, providing shelter to cattle during any disaster. • Zoning is done on the basis of sun orientation to avoid heat gain.
Resilience	• Making the structure flood resilient by roof overhangs, elevated platform, shelf and wet floodproofing. • Taking flood mitigation measures such as vertical evacuation and precautions based on an emergency, transitional or permanent phases. • Making earthquake-resistant buildings via bracing and performing seismic checks. • Implementing a Single wall system via Mud straw render and other precautionary measures for durability against fire. • Treatment of bamboo and other materials to make them water and termite resistant.
Water	The goal of reduced water consumption and a net-zero water cycle was achieved by optimized solutions which include efficient rainwater harvesting, greywater treatment, water-saving fixtures and sufficient water storage capacity post during floods.
Energy	Reduced the daily energy consumption by around 50.34% by dropping Energy Demand from 10.69 kWh to 5.35 kWh. Annual energy consumption is 3650 kWh and the annual energy production is around 3902.56 kWh thereby making our building a net energy-efficient building. The value of epi calculated for our site is **59 kWh**.
Engineering design	The goal of an engineering design approach was to compare the results of data including lighting data, energy data, and cooling load estimation to the stimulated results from the design-builder software. The lighting data revealed that our building has an ample amount of sunlight in all the rooms thereby eliminating the need for lighting consumption. Using efficient battery management and storage grids that are optimized by using the MPPT algorithm.
Affordability	The goal was to create a cost-efficient design with an optimum solution without compromising any aspect of the shelter design with a swift construction within 8 months. Instead of a conventional brick, zerund bricks are used in the design, also locally available materials like bamboo, mortar with mud, rice husk, and cow dung have been used. Service areas placed at designated areas to reduce plumbing cost as well as minimum cost on the excavation on the selection of pile foundation has also been done. Withholding of conditioned rooms and minimal expenses on heavy furniture are some other factors that have been taken care of.
Scalability	To resolve major local issues, use local materials, easy to maintain, low carbon footprint, spatial flexibility for large scale implementation.
Innovation	• Partition walls-Use of partition walls to segregate spaces instead of using permanent walls. This reduces the cost of construction and helps in making the project affordable. • Foldable furniture • Daylight(Ensured to all units) • Therapeutic Benefits(Landscape view) • Passive cooling and cross-ventilation (Ensured to all units) • Cost-efficient and feasible water requirements.
Health and Well Being	The goal is to achieve a design with adequate Physical, Emotional & intellectual and social well-being with better indoor air quality, comfort, water quality, health and sanitation, and privacy and security.

Fig 4. Goals and Solutions

DESIGN EVOLUTION AND PLANNING

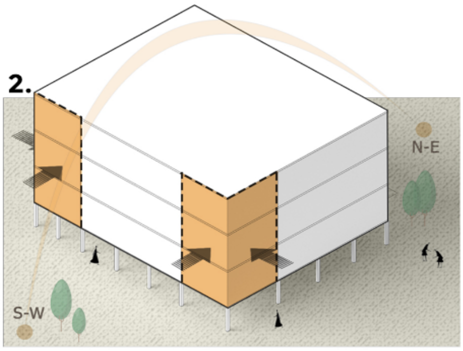
CONCEPTUALISATION

1.



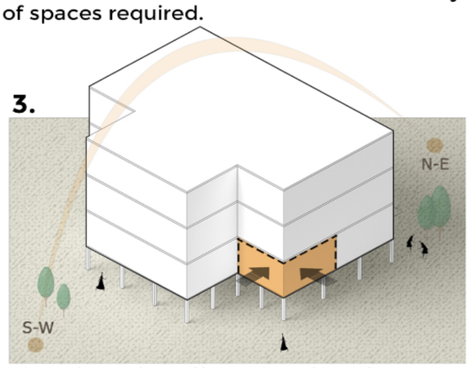
The concept consisted of taking the sun path into consideration which affected our building orientation.

2.



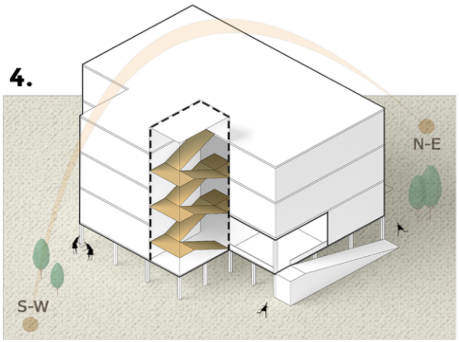
With respect to orientation, shape is also derived to achieve the maximum efficiency of spaces required.

3.



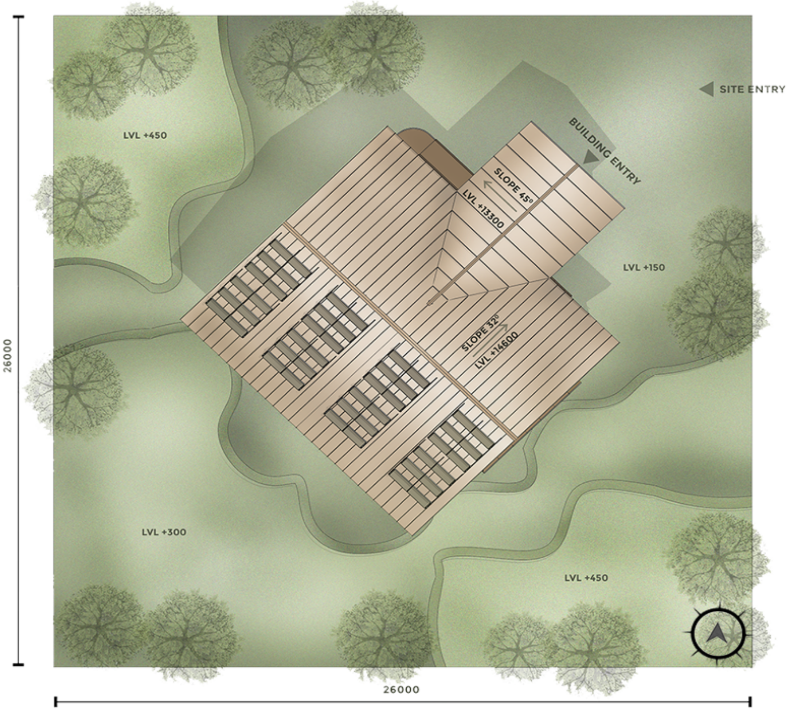
The orientation affected zoning of our rooms (services on the SW side where heat gain will take place and other rooms on NE where day light is received)

4.

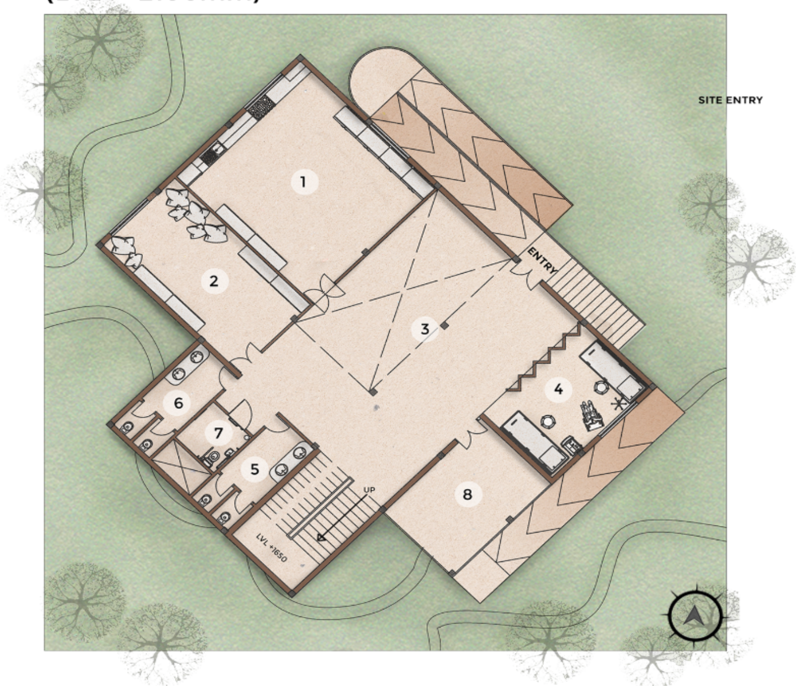


Natural ventilation is also introduced with the help of stack effect where jali play an important role in our design to achieve natural ventilation.

SITE PLAN



STILT FLOOR PLAN
(LVL : +2100mm)

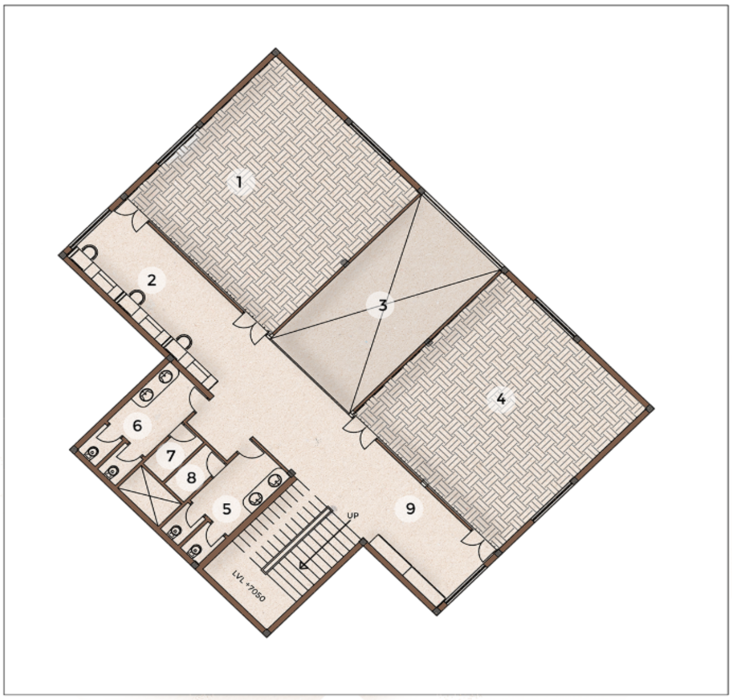


LEGENDS

1. Kitchen	50 sqm	5. Male washroom	10 sqm
2. Storage	28 sqm	6. Female washroom	10 sqm
3. Community hall	82 sqm	7. Handicap washroom	6 sqm
4. Medical room	20 sqm	8. Cattle shelter	25 sqm

Fig 5. Conceptualisation and Floor Plan I

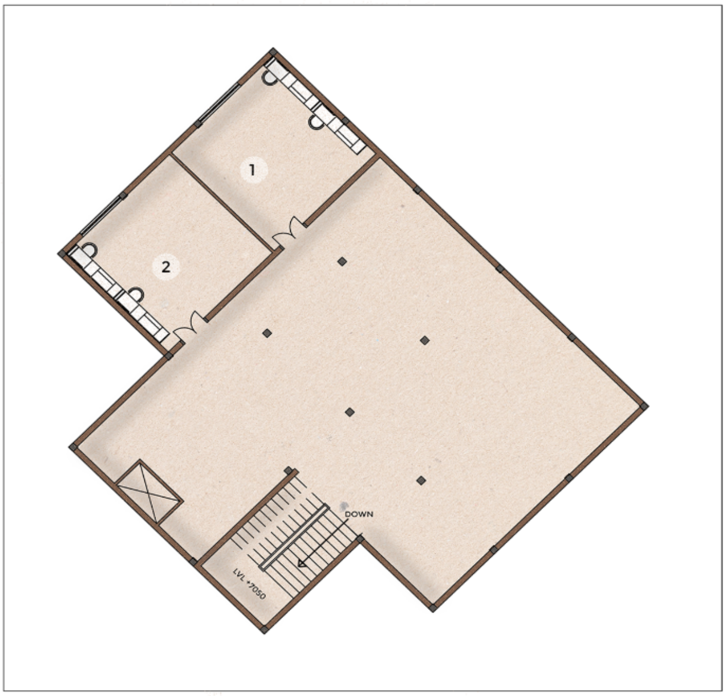
FIRST FLOOR PLAN
(LVL: +5400mm)



LEGENDS

1. Male dormitory	55 sqm	6. Female washroom	10 sqm
2. IT cell	20 sqm	7. Female bathing area	3 sqm
3. Double height cutout	20 sqm	8. Male bathing area	3 sqm
4. Female dormitory	55 sqm	9. Reading area	20 sqm
5. Male washroom	10 sqm		

TERRACE FLOOR PLAN
(LVL: +8700mm)



LEGENDS

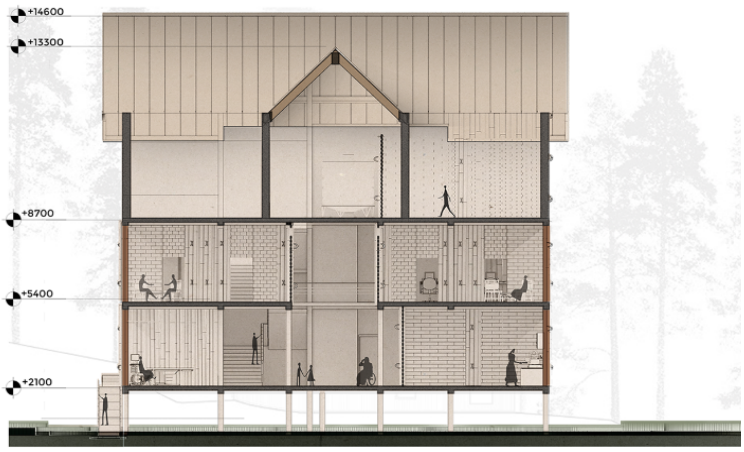
1. Electrical room	28 sqm
2. Control room	28 sqm

Fig 6. Floor plan, elevation and section

ELEVATIONS AND SECTIONS

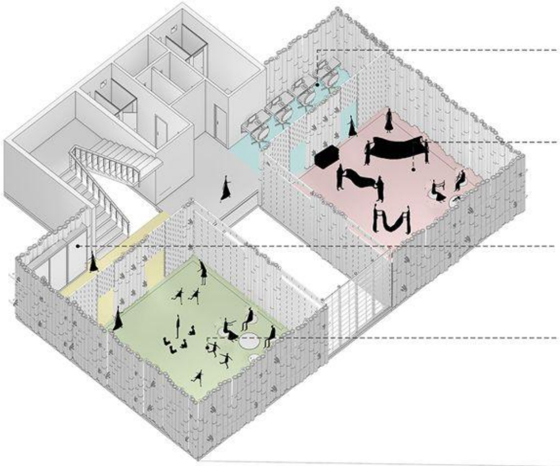
SECTION THROUGH STAIRCASE

NORTH EAST ELEVATION



SECTION THROUGH DOUBLE HEIGHT

BEFORE DISASTER SCENARIO

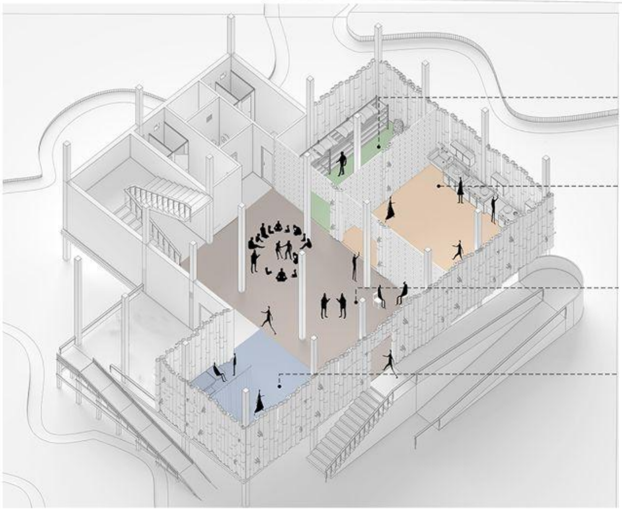


Computer units with printers are installed for aid to local people.
(Preparing identity documents etc.)

Dedicated room for female self-help groups to practice local handicrafts promoting regional art forms.
(Encouraging them to become income wise self-reliant)

Some collection of books and current affairs can be made available for local people over here.

Dedicated room for toddlers who come along with their mothers can socialize with other children there ensuring their physical and mental development.



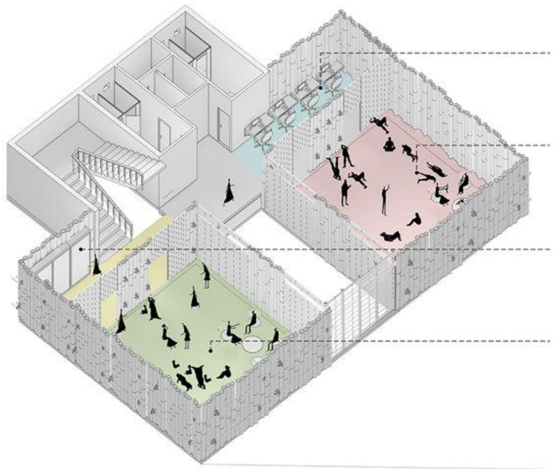
Provision of store room for stacking of non – perishable staple food items that can cater to daily food demands during floods.

Community kitchen can be used by commoners to prepare food for services like mid-day meal and other social activities.

Large community gathering space for local people to set up panchayats, information about awareness programs on government schemes.

Medical room to ensure healthcare of local people in terms of regular bp check-up machines, providing basic first aid facilities in immediate response to any medical condition.

DURING DISASTER SCENARIO



Computer units with printers ensures a continuous communication link of resilience shelter with nearby emergency help facilities in proximity.

Room can be used as a male dormitory for local people to stay until the flood situation comes under control.

Collection of books alleviate the state of mind of people during floods.

Room can be used as dedicated female dormitory for local women to stay until the flood situation comes under control.

Storage area becomes a prime area from where all essential material will be supplied.

Community kitchen will become a service area for all food preparation throughout the day.

Community gathering area will be converted as an extended space for medical room to deal with medical conditions of local people.

Cattle can be moved over the stilt level via ramp ensuring them a safe place to stay during floods.

Fig 7. Before and during disaster scenarios

SECTIONAL VIEW THROUGH DOUBLE HEIGHT

SECTIONAL VIEW THROUGH STAIRCASE

Fig 8. Sectional view of Community Resilience Shelter

Our site is prone to various natural calamities and health hazards, which include Floods, earthquakes, Fire, vector and water-borne diseases and also concerned about the present COVID -19 scenario. While Health Hazards and the impact of vectors (disease carriers/pests in animals) will be covered in the contest under health and safety, this section aims to provide our structural as well as mitigation measures in case of floods, earthquakes and fire. Since floods are the most frequent cause of disruption at our site, our design incorporates a mix of both structural and mitigation measures to make our shelter flood resilient.

Floods are generally caused by dam overflow due to heavy rains during the monsoon season. Hence, our structure is designed to withstand both heavy rains and standing/moving water flow.

Following are the measures taken:

A.	A.HEAVY RAIN	B.	STANDING WATER
			Measures to keep shelter rigid:
1	Water resilient plasters	1	Foundation to adequate depth in original ground (not fill material)
2	Roof overhang	2	Waterproof materials such as stabilized soil to above level of standing water.
3	Drainage		**Measures to keep belongings dry:**
4	Toes or plinth protection and other sacrificial mass	3	Platform (External dry areas)
		4	Raised floors (Internal dry areas)
		5	Shelf (limited internal dry areas)
		6	Accessible roof

Table 3. Measure against rain and water

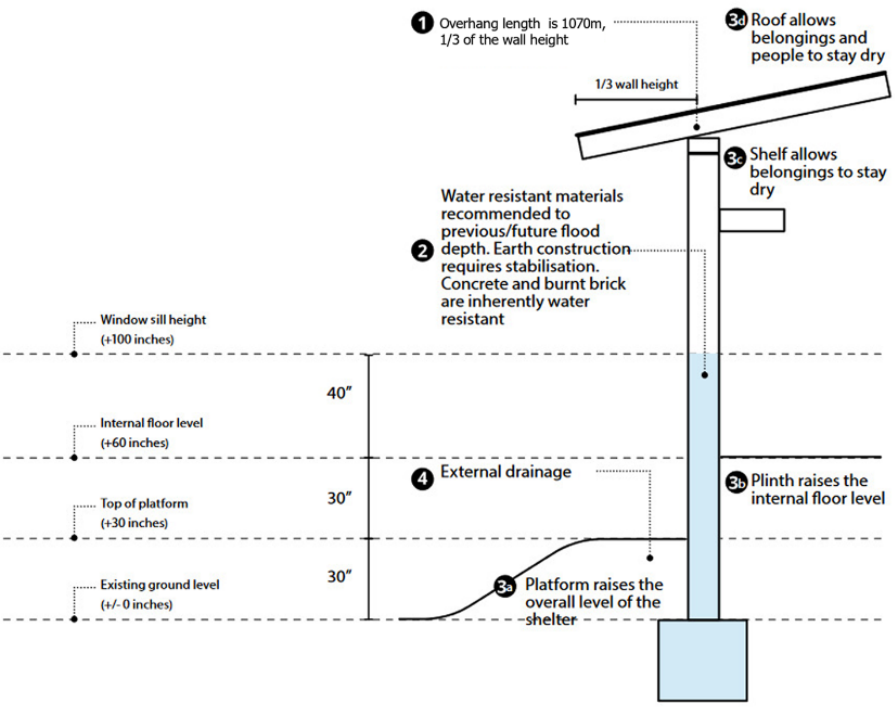
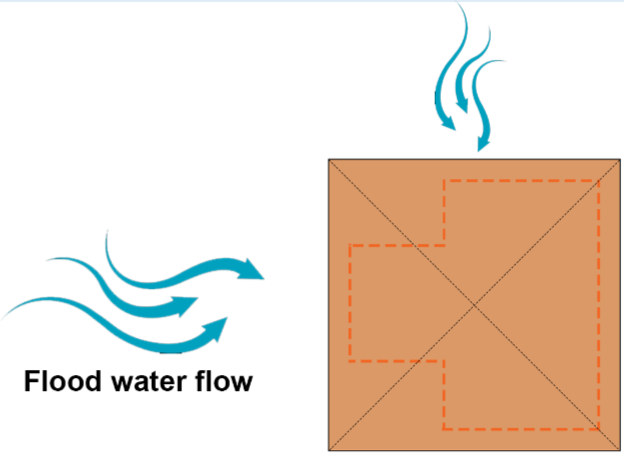


Fig 9. Illustrative view of the measure taken

Further , we have provided square design and a diagonal orientation which provides an edge in combating flood.



Squared shaped houses are preferred as they are generally stronger in flood conditions

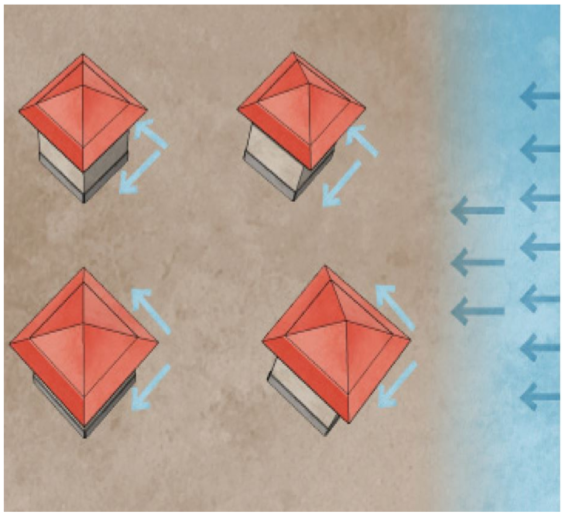


Fig 10. Flood resisting orientation

For foundations, we have provided pile foundations.

Pile foundations consist of long and slender structural elements that are used for elevated buildings usually constructed of steel, precast concrete or treated timber.

Pile foundations are considered to be deep foundations since they are built deep in the ground so that they resist vertical and lateral loads by using the deeper layers of soil's resistance.

Pile foundations are used in situations where flood depths and velocities can be high, allowing the floodwaters to move below the elevated floor without damaging the building.

Some of the fundamental aspects of pile foundations are the pile size and spacing between single elements, embedment depth, installation method, bracing and connections to the building.

When using piles in combination with grade beams, greater resistance to rotation of the building is achieved.

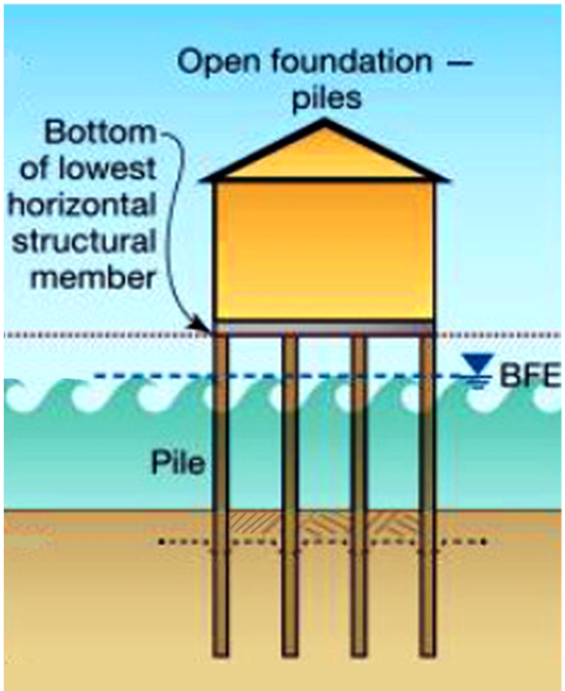


Fig 11. Pile foundation

Apart from the elevation measures , our structure also incorporates wet floodproofing strategies.

The benefit of wet floodproofing is that if flood waters are allowed to enter the enclosed areas of the house and to quickly reach the same level as the flood waters outside, the effects of hydrostatic pressure, including buoyancy, are greatly reduced.

As a result, the loads imposed on the house during a flood, and therefore the likelihood of structural damage, may be greatly reduced.

Wet floodproofing is generally used to limit damages to enclosures.

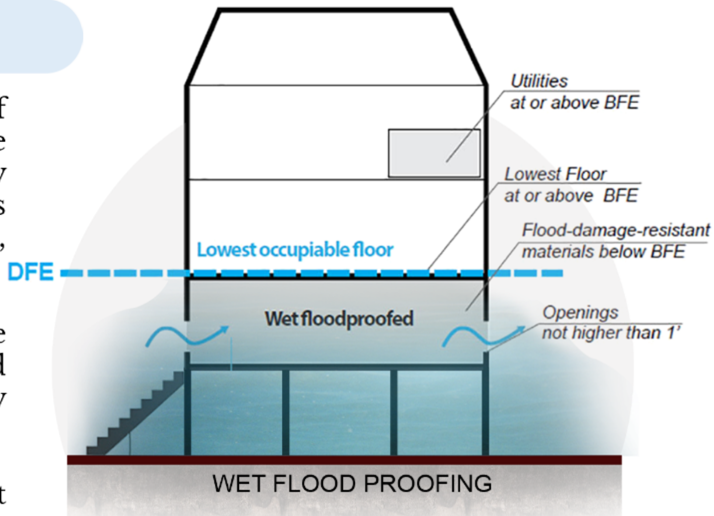


Fig 12. Wet Floodproofing strategy

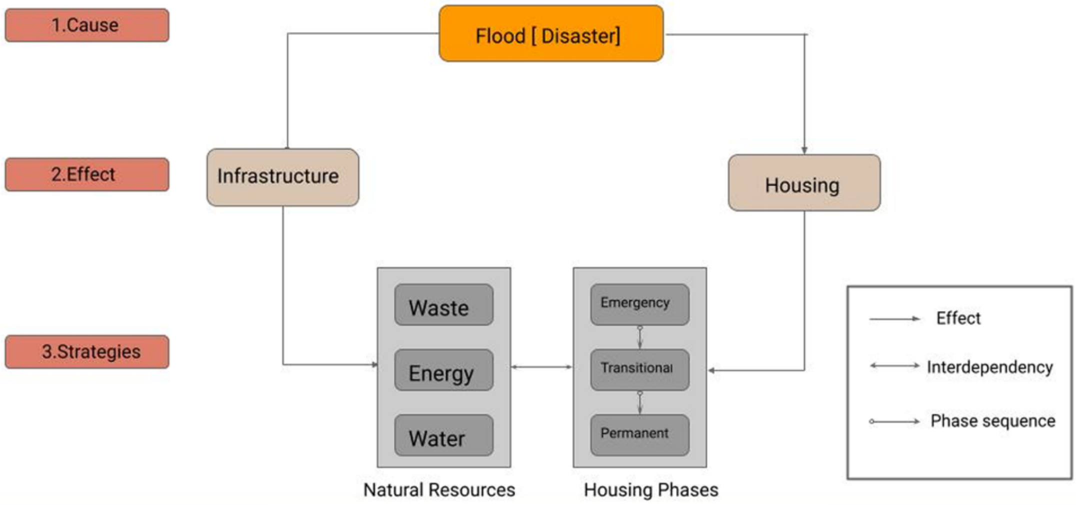


Fig 13. Disaster Response Integration

PROACTIVE MEASURES FOR PROLONG STAY IN SHELTER DURING FLOODS:

- Ensuring emergency stay of local people for a few days by incorporating vertical evacuation and utilizing emergency food, water, and energy storage.
- For Transitional stay (may include duration of few weeks or a month) by incorporating utmost emergency measures, food and water distribution.
- For Permanent Stay (for more than a month) -Reduction in daily activities of individuals shall be accompanied by reduced calorie intake hence food storage can be extended for a few more days.
- Abstaining consumption and storage of salty foods as they demand additional water consumption.
- Essential items like whole-grain cereals and canned foods with high liquid content and ORS solutions can be made available in stock prior to floods. Provision of disaster supply kits should include medical supplies like BP checkup machines, first aid kits and respirators.

QUANTIFICATION OF RESILIENCE

DURING FLOODS	QUANTITY	NOTES
Number of people	128 people	Shelter is designed to accommodate nearly 128 people taking into account of their per person area for daily activities and other necessary requirements such as food, hygiene etc.
Cattle accommodation	8-10 animal	Cattle can be shifted to the stilt level via ramp ensuring their safety during floods.
Water storage	50 cum	1. Maintenance of water tank and its components against clogging/contamination post every flood event. 2. Keeping its hygiene intact both around the tank and internally.
Water tank maintenance	Every 3-4 months (End of dry season and before first rain plus post every flood event)	
Dry food storage	50 cum of storage (Volume of room excluding circulation space)	To meet daily food requirements of instant cereals, pulses, rice, vegetables, cooking oil dry storage is provided. Rationed according to emergency, transitional or permanent housing phase
Bamboo fire rating	30 minutes	1. Taking into account the climate of Golaghat Assam, bamboo is less vulnerable to fire as it is mostly humid and temperate throughout the year. 2. Mud plaster layer on either side of bamboo can increase its fire rating to few more minutes.
Bamboo life span (as construction material)	4-7 years span	1. Life span of bamboo as construction material can be increased to 4-7 years on treatment with borax-boric acid solutions for protection against fungal attacks and abrasion resistant. 2. Check for maintenance/replacement post every flood event.
Safety gears	4-5 kind of safety gears stock.	1. **Disposable rubber boots:** 20-25 pairs (Pathogen resistant). 2. **Disposable coveralls (hoods):** 20-25 pairs 3. **Respirators:** 5-7 4. **Neoprene life jackets:** 20-25 5. **Deck boats:** 2-3

Table 4. Quantification of Resilience

POST FLOOD MEASURES:

Provision of safety gears like neoprene life jackets, disposable rubber boots is also mandatory. Deck boats to ensure rescue of people nearby.

Discharge of contaminated flood water as stagnant water may lead to water borne disease. Implementing fumigation measures.

Removal of debris around the site and repairing the roof drainage system in order to ensure protection of the building from future damage.

Repairing/ Maintenance/ Replacement of Wall Panels, floors and other structural/ non structural members.

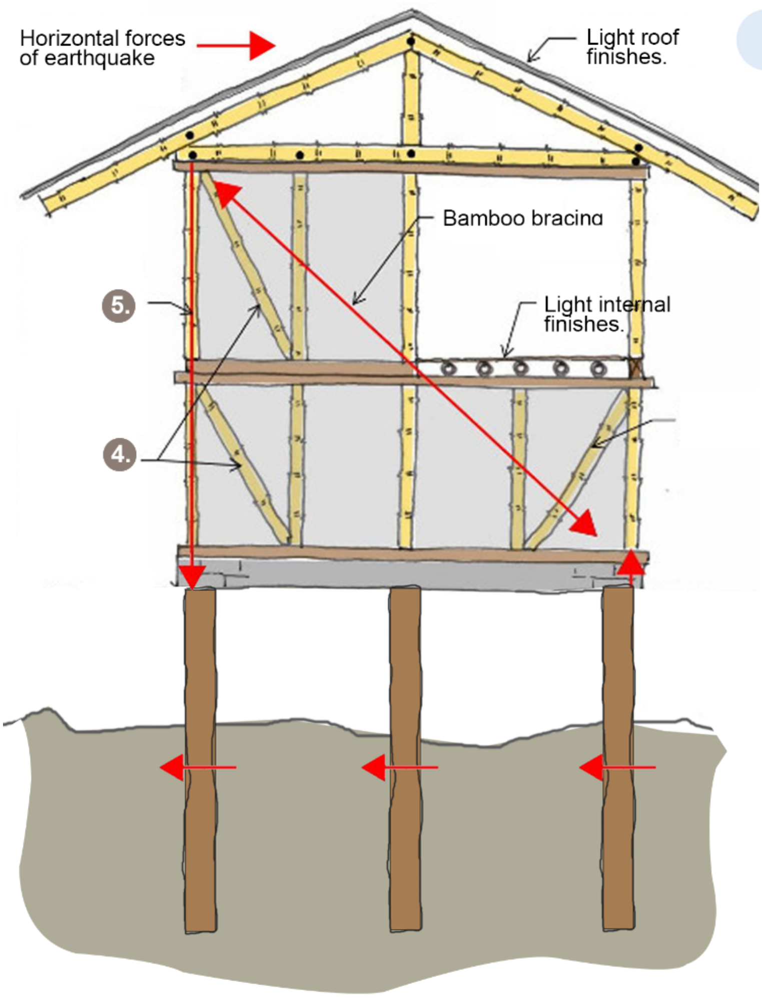


Fig 14. Earthquare resistance measures

B. RESISTANCE AGAINST EARTHQUAKE

1. The shelter is designed to be structurally stable even in during an earthquake, in addition to the suitable grid column and beam placement, measures have been implemented to resist the lateral movement during an earthquake.

2. Bamboo bracing has been provided in between the framed structure, since bamboo can handle tension and compression better than steel reinforcements.

3. Since earthquake effects are proportional to weight of the building, bamboo being light weight material, bracing made using bamboo does not add any significant weight to additional seismic load.

4. Bamboo bracing are symmetrically placed in both directions.

5. Seismic analysis has been done for the required seismic zone V for lateral deflection and overturning.

6. The values of deflections caused by earthquake will not result in structure failure.

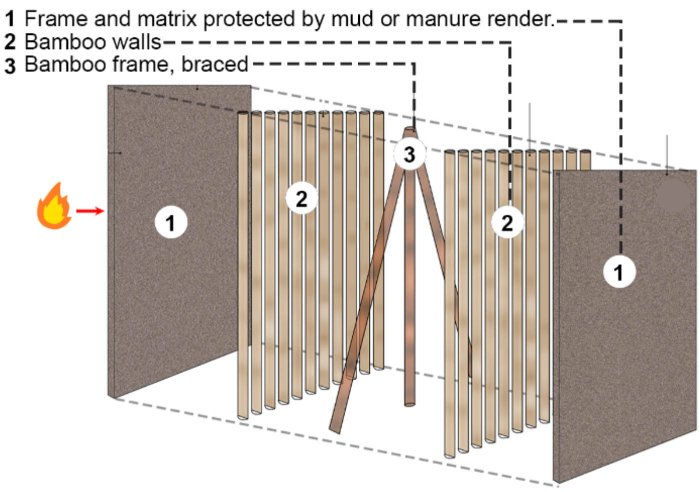


Fig 15. Fireproofing of walls

C. DURABILITY AGAINST FIRE

Single wall system including mud-straw render protects the structure; analogous to the passive protection that gypsum plasterboard provides to steel columns.

Other considerations for reducing the risk of fires in engineered bahareque housing includ- Education of occupants on risks of fires,installation of smoke detectors and fire extinguishers, not storing flammable materials inside the houses,ensuring electrics are installed to a good standard electrics common reason for fires.

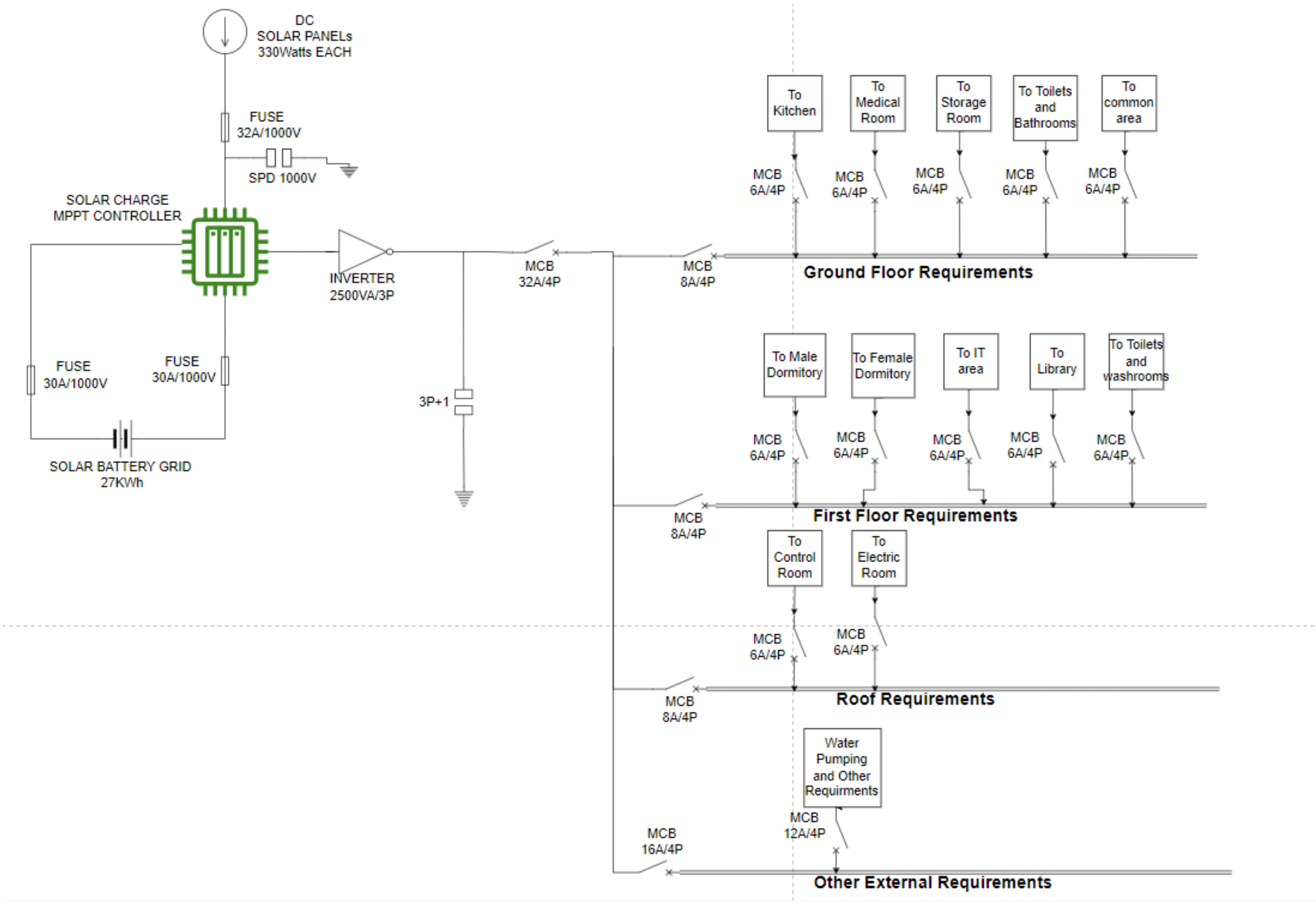


Fig 16. Electrical SLD for the building

- With lighting simulations, the base case scenario was derived from high lighting consumption which was then achieved a lowered lighting power consumption. With the reduction of power, LEDs were chosen.
- The optimum daylight factor for our design has been derived through multiple simulations, helping to achieve the best possible positions for electrical equipment.
- The Maximum Power Point Tracking Algorithm (MPPT) for maximizing the incident solar energy.

Solar Charge Controller Circuit

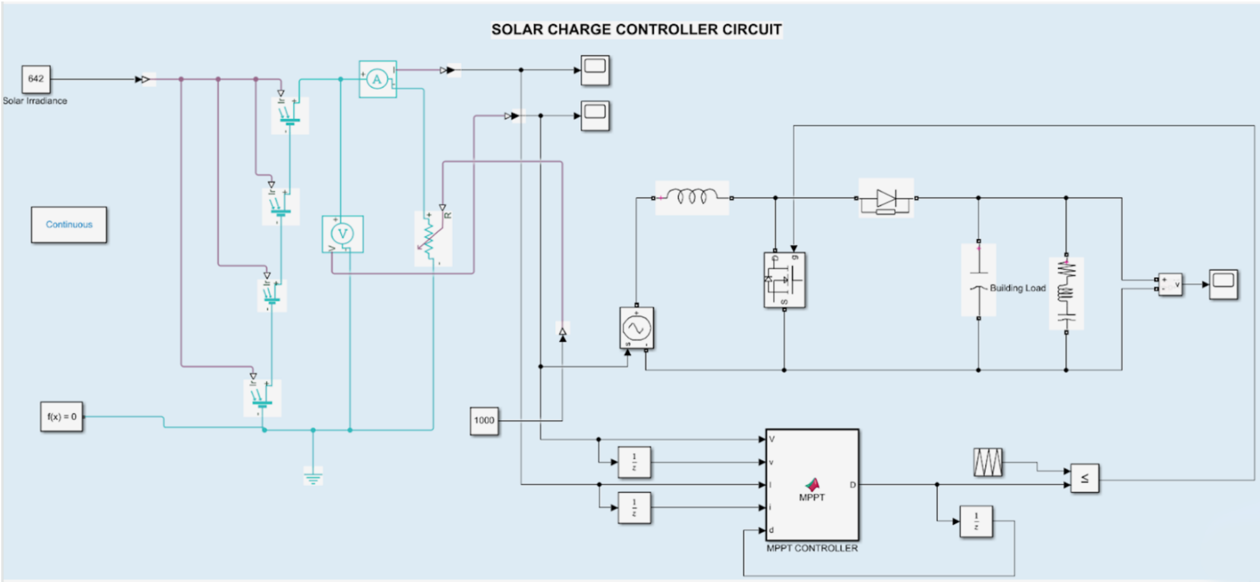


Fig 17. Solar Charge Controller Circuit

Observations made after using the MPPT algorithm setup:-

- The algorithm setup achieves the maximum power by varying the Impedance as visible to the Solar Panel. A constant and stable terminal voltage of 230 Volts, which is the standard single-phase supply in India, was derived.

- Using the MPPT algorithm helped to improve the efficiency of the solar energy captured as it helps to reduce the energy losses that were earlier encountered when it was not tracking the point of maximum power in the IV characteristic curve of a solar PV.

- Another important aspect in Engineering and Energy Design is the use of Power Grids, utilizing the best available power grid so that we can store the energy produced efficiently. Thus used the FLOW Battery Management System because of its various advantages that are very less Power Loss or degradation, no inherent lifespan limitation for the energy being stored, it is assumed to be the ideal choice for merging with solar cells, utilizing the Active Battery Management system along with MPPT guided Solar Panels ensures proper storage of energy in the battery and very less energy is wasted while charging the entire battery.

HEALTH AND WELL-BEING

PHYSICAL WELL-BEING

INDOOR AIR QUALITY

1. With the no smoking policy inside the building ensuring tobacco smoke control.

2. Exterior fenestration in the 1st floor ensure the maximum fresh air ventilation of the building as well as exterior windows at the optimum position also ensure the same.

3. With minimum use of concrete in the structure and replacing 80% of the wall material with composite material like bamboo layered with mud, rice husk and cow dung, reduces CO_2 emission as well as bamboo assembled components have approximately 37% chance of reducing CO_2 and other greenhouse gases from atmosphere ensuring a better indoor air

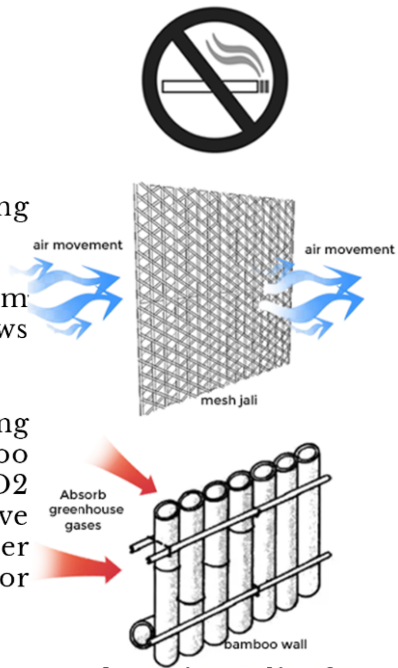


Fig 18. Indoor air quality features

WATER QUALITY

Quality of treated water or recycled water with estimated pH value from 6.5-9 which is reused for flushing and other similar applications, ensures physical parameters. A drainage system has been provided separately at the rear end of the building, separated and fully covered ensuring the minimum risk of diseases spreading from there.

HEALTH & SANITATION

1. With separate designated areas for facilities like work space, washrooms, kitchen/ pantry, service areas, etc, reduce the risk of spreading respiratory and other communicable diseases.

2. Mesh behind the jaalis and all other windows ensuring the vector control inside the building and also with bamboo shutters over the window helps to control outdoor dust pollutant.

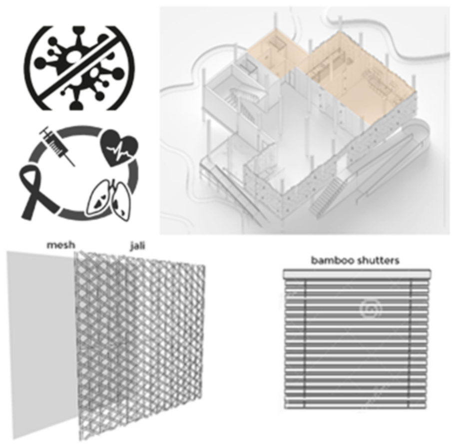
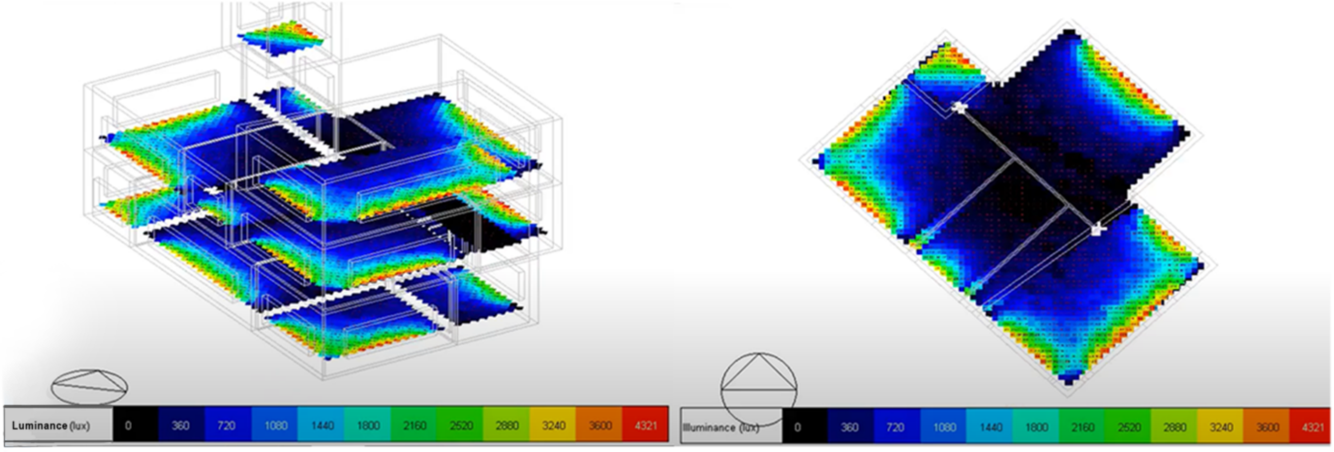


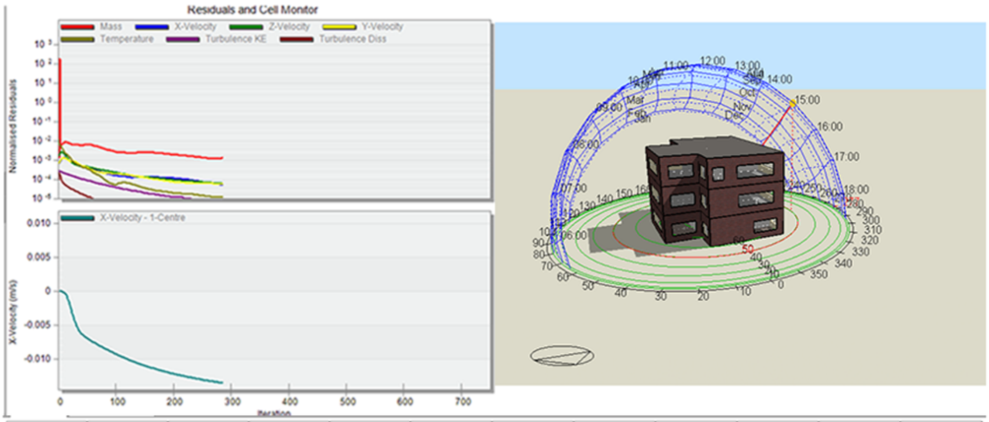
Fig 19. Pollutant control measures

PRIVACY & SAFETY

Separate area designated for male and female dormitories, bathing area, washrooms, etc. ensuring privacy. Lockable doors and windows are also provided keeping in mind the security of the occupant.area, washrooms, etc. ensuring privacy. Lockable doors and windows are also provided keeping in mind the security of the occupant.

COMFORT





We analysed the daylighting data of our building using the design-builder simulation and found out that our building remains lighted throughout the day, without the need for any artificial light

Block	Zone	Floor Area (m2)	Floor Area within ...	Floor Area within ...	Average Daylight...	Minimum Daylight...	Maximum Dayligh...	Uniformity ratio (...	Uniformity ratio (...	Min Illuminance (l...	Max Illuminance (...
Block 3	Zone 1	83.746	53.810	64.253	6.233	1.233	20.621	0.198	0.060	123.82	2070.34
Block 3	Zone 2	54.123	33.075	61.111	5.882	0.756	21.492	0.129	0.035	75.75	2153.44
Block 3	Zone 3	25.513	6.475	25.379	2.455	0.204	16.800	0.083	0.012	20.46	1682.27
Block 3	Zone 4	54.422	31.463	57.813	5.675	0.844	20.225	0.149	0.042	84.58	2027.81
Block 2	Zone 2	86.178	29.967	34.773	3.262	0.024	19.034	0.007	0.001	2.42	1908.08
Block 2	Zone 3	53.018	31.019	58.507	5.719	0.708	20.264	0.124	0.035	70.89	2028.81
Block 2	Zone 4	26.471	6.710	25.347	2.437	0.211	16.658	0.087	0.013	21.12	1667.55
Block 2	Zone 1	52.177	28.924	55.435	5.419	0.848	21.045	0.156	0.040	84.89	2107.13
Block 1	Zone 2	39.550	27.685	70.000	5.932	0.863	17.917	0.145	0.048	86.09	1787.94
Block 1	Zone 6	94.810	17.702	18.671	2.194	0.192	20.252	0.087	0.009	19.12	2018.97
Block 1	Zone 3	15.677	4.703	30.000	2.470	0.469	11.330	0.190	0.041	46.83	1131.16
Block 1	Zone 1	15.677	15.050	96.000	8.593	2.221	19.019	0.258	0.117	221.64	1897.67
Block 1	Zone 4	18.858	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00
Block 1	Zone 5	32.725	24.448	74.706	7.115	0.836	21.581	0.118	0.039	83.65	2159.23
Total		**652.945**	**311.029**	**47.635**	**4.583**	**0.000**	**21.581**	**0.000**	**0.000**	**0.00**	2159.23

Fig 20. Illuminance Analysis of CRS

EMOTIONAL & INTELLECTUAL WELL-BEING

By developing a green landscape, with an adequate number of trees on the site, with all the fa cilities within the site and providing connectivity, thereby enhancing the emotional well-being of the occupants. The double-height in the design will provide comfort from possible claustrophobia and allow people to breathe mentally.

SOCIAL WELL-BEING

In pre-disaster time the shelter will be used as a place to generate employment for women with local artwork and as well as a daycare will also be provided ensuring the social well being of the local community

WATER PERFORMANCE

1. Supply, demand & storage data

Being a flood-prone site, our category of months changes on an annual cycle, and so does the number of residents. In general months, a residential crowd of 20 people and a crowd of 25 people as moving has been considered. During flood and post-flood months, 128 people are considered to shelter residents. Water consumption per capita per day by the calculations, as well as by the guidelines, is around 135 lpcd. Through innovative approaches like using pressure regulators and dual flush toilets, we were able to reduce this figure from 135 to almost 96 lpcd.

Purpose	Per head usage per day(lpcd)	Occup-ants	Reduction percentage	Total consumption per day (without reducers)	Reduction percentage	Total Consumption per day (after using reducers)
Drinking	5	128	0	640	0	640
Bathing	40	128	40% (Pressure Regulator)	5120	40	3072
Flushing	25	128	27% (Dual Flush Toilets)	3200	27	2336
Cooking	5	128	0	640	0	640
Washing Clothes	25	128	25% (Pressure Regulators)	3200	25	2400
Washing Utensils	20	128	25% (Pressure Regulators)	2560	25	1920
Cleaning	10	128	25% (Pressure Regulators)	1280	25	960
Others(Washing hands, Brushing etc)	4.5	128	25% (Pressure Regulators)	576	25	432
TOTAL CONSUMPTION(LPD)				**17216**		**12400**
TOTAL CONSUMPTION per person per day(LPCD)				**134.5**		**96.875**

Table 5. Water Consumption (during and post-flood Months)

Purpose	Usage For residents (15-30)(lpcd)	For moving crowd (20-30)	Reduction percentage	Total consumption per day (without reducers)	Reduction percentage	Total Consumption per day (after using reducers)
Drinking	5	0.5	0	112.5	0	112.5
Bathing	40	0	40% (Pressure Regulator)	800	40	480
Flushing (Considering 2 big flushes and 2 small flushes per day)	25		27% (Dual Flush Toilets)	500	27	365
Cooking	5	0	0	100	0	100
Washing Clothes(Considering 3 clothes per person per day)	25	0	25% (Pressure Regulators)	500	25	375
Washing Utensils	20	0	25% (Pressure Regulators)	400	25	300
Cleaning	10		25% (Pressure Regulators)	200	25	150
Others(Washing hands, Brushing)	4.5	2	25% (Pressure Regulators)	140	25	105
TOTAL CONSUMPTION(LPD)				**2752.5**		**1987.5**

Table 6. Water Consumption (General Months)

After considering the whole consumption data, we had to look for our water sources. In our cycle, harvested rainwater and municipality are the main water sources. If we consider the first month (major rainfall month) from the calculation (refer to annexure, Page 10), we can see that the harvested rainwater is almost 120 kL while the municipality supply for the same month is almost 198 kL (considering the municipality supply of 100 lpcd in general months and 50 lpcd in flood and post-flood months with a disruption factor of 50%, Ref: Assam govt. website). Also, the freshwater demand for the said month is almost 294 kL while the total supply remains to be 318 kL. So, by calculating the net demand vs consumption data, we were able to get a positive margin of almost 24 kL. Thereby we tried to calculate a new and less reliable municipality supply by using 85% of the margin amount to reduce the reliability of municipality supply and the rest of 15% was used to store an amount of around 50kL in our water storage tank (underground) to use it as an emergency reserve when needed.
Also, around 65% of greywater is generated from freshwater demand which will be treated in a greywater treatment setup with an efficiency of 75%. Note:

The net water cycle is always positive on a monthly scale (Refer to Annexure, Page 10) There's no necessary need for extra storage. The positive part (accumulation) of every month can be flushed out. But considering any kind of emergency (during flood more probably), an underground storage tank of 50kL is added to the cycle.

2. **Addressing the challenges and constraints**

01	Disruption of municipality water supply	• Efficient rainwater harvesting to meet primary demands. • Treatment of greywater to meet our flushing demands. • Dependence on municipality was reduced by 25%
02	Minimal ground coverage	• Construction of elevation was avoided due to minimal ground coverage. • To prevent storage/treatment setup from floods on-ground construction was also avoided.
03	Disaster management measures	• Deep construction was avoided due to earthquakes. • Flood proofing on underground water systems were done. • Water system maintenance prior/post every flood event
04	Cost constraints	• Cost effective solution was proposed for treatment of greywater and rainwater.
05	Water quality/ Efficiency	• To ensure water quality cost effective Rainy water filters and disinfectants were used. • Grey water treatment efficiency was enhanced by using disinfectants, activated carbon filter bed and multi-grade filter bed.

Fig 21. Water design challenges

3. Addressing challenges in stormwater management

- To harvest stormwater, we need to decrease the porosity of the ground for which a layer of concrete over the ground has to be made. Since we were able to achieve a net-positive water cycle, harvesting stormwater is not a necessity.
- Unless there is a need, installing a stormwater management system wouldn't be economical.
- As our site lies in flood and earthquake-prone areas, unnecessary underground storage tanks wouldn't be feasible.
- We are providing contours in our resilience shelter which will help us to manage the accumulation of flood/stormwater to a wider extent.

4. Water system diagrams

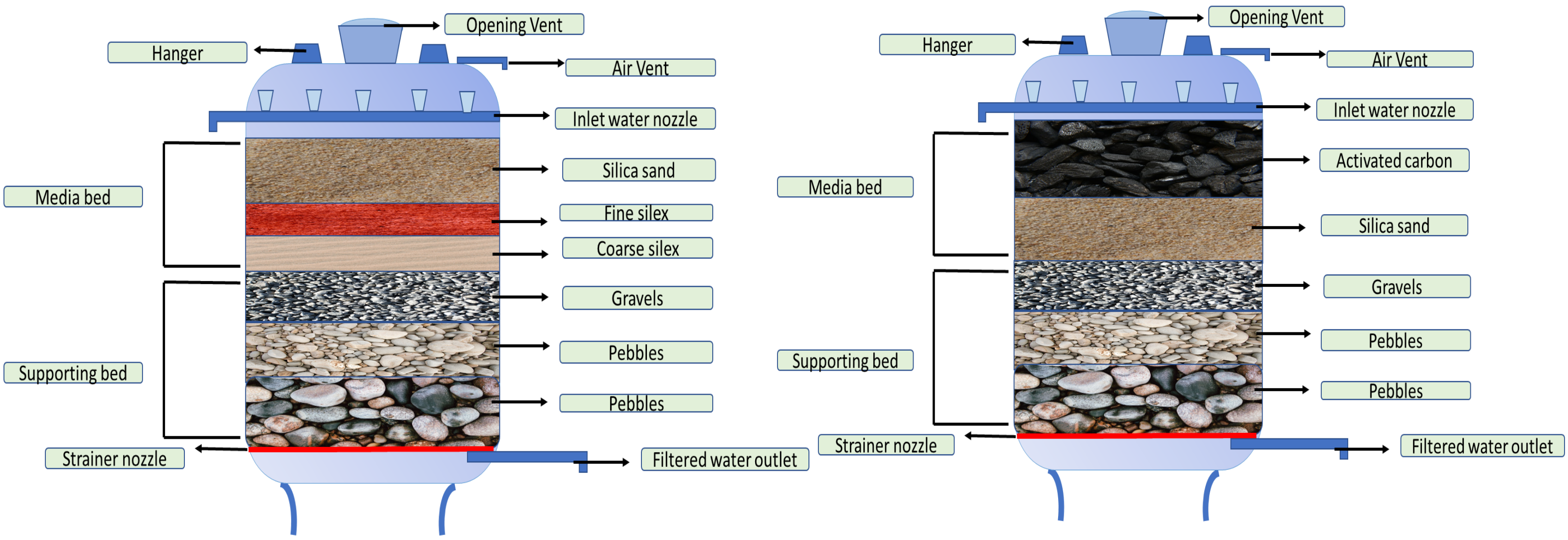
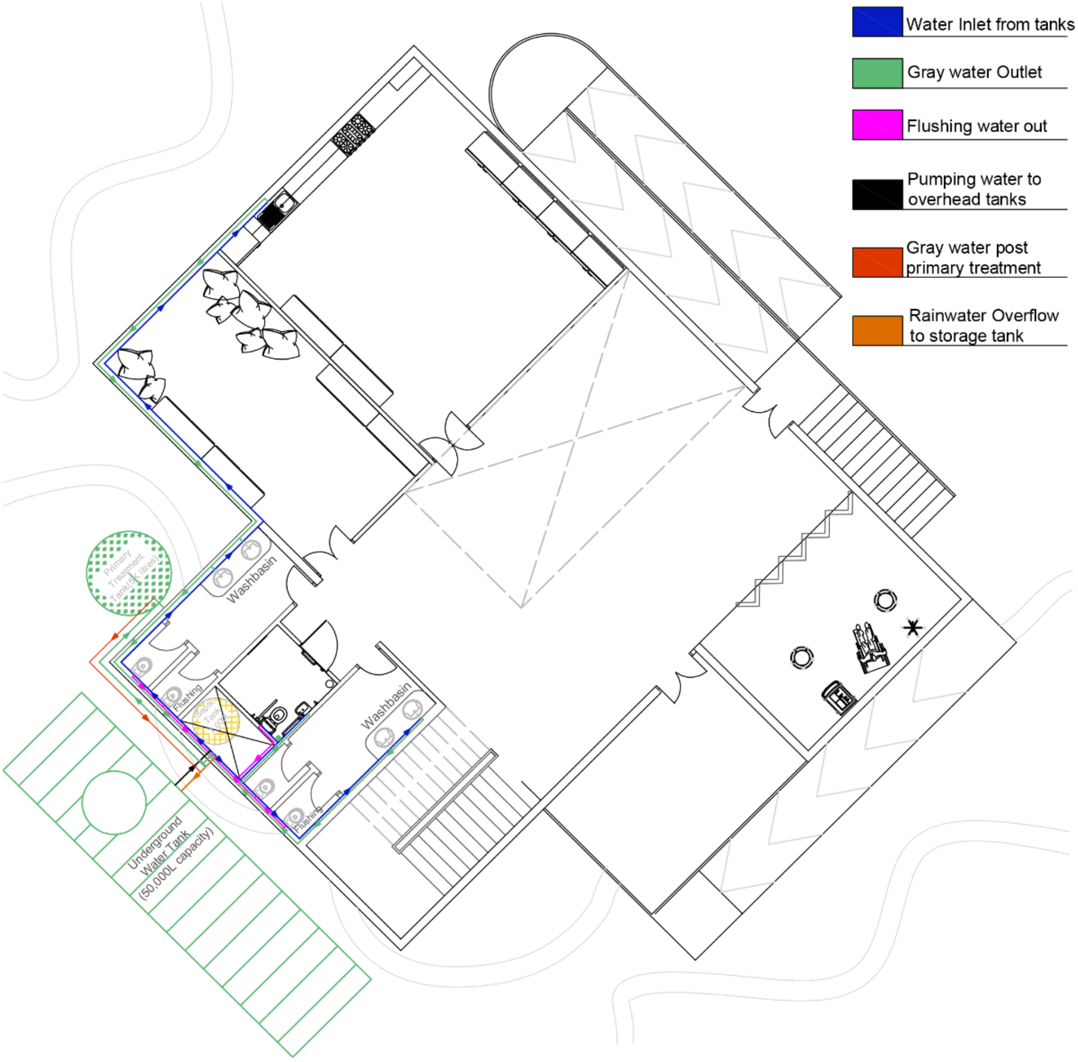
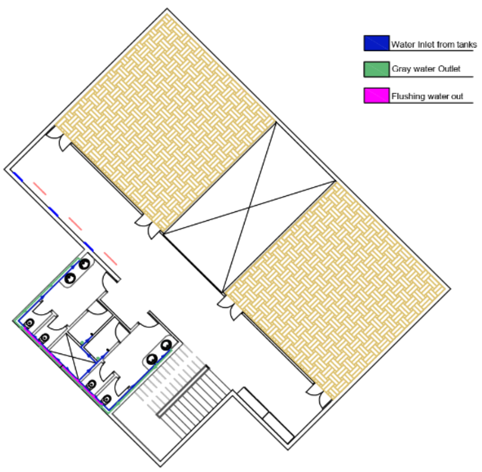


Fig 22. Filter-bed composition

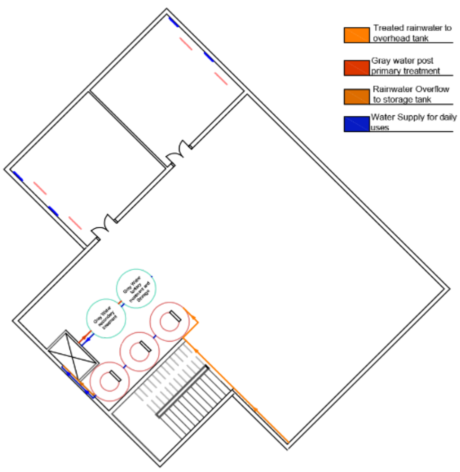
Fig 23. Rainy water filter



Plumbing Layout - Ground floor



Plumbing Layout - First floor



Storage and treatment tanks

Fig 24. Plumbing Layout

ENERGY PERFORMANCE

To maximize the energy performance of any building, there are two components reducing energy consumption and simultaneously increasing energy generation

Reducing Energy Consumption

We took various measures to reduce the energy consumption:

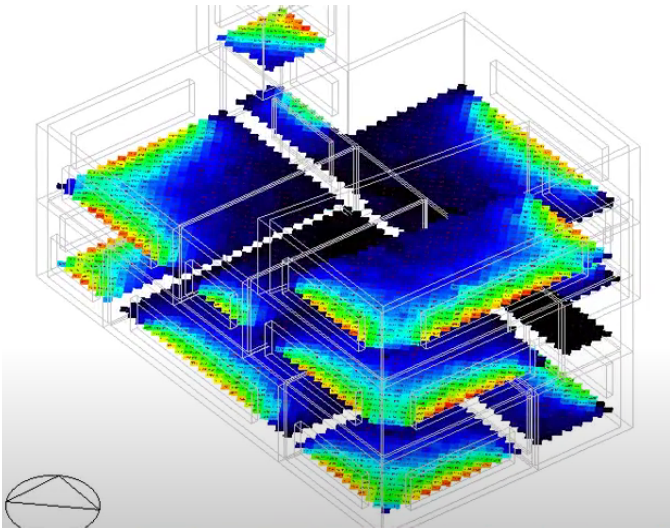
- A comparative study was performed by changing WWR(Window wall ratio) and changing the glazing type from Single glazing to Double Glazing.
- An efficient lighting simulation was performed so as to obtain the appropriate placement of lights within the building to reduce the energy consumed in lighting the building.

The results for efficient lighting simulations are

Eligible zones for daylighting

Block	Zone	Floor area (m2)	sDA area in range (m2)	sDA % in Range%	ASE area in range (m2)	ASE % in range
Block 1	Zone 6	94.9	20.55	21.65	78.30	82.5
Block 1	Zone 2	39.8	39.47	99.22	39.78	100.0
Block 1	Zone 1	15.8	15.78	100.00	3.02	19.1
Block 1	Zone 3	15.8	9.98	63.24	15.78	100.0
Block 1	Zone 5	32.9	32.87	100.00	18.24	55.5
Block 1	Zone 4	19.0	18.86	99.42	18.97	100.0
Block 4	Zone 1	9.0	9.01	100.00	7.55	83.8
Block 2	Zone 2	86.6	64.76	74.78	86.60	100.0
Block 2	Zone 3	53.2	52.50	98.67	33.82	63.6
Block 2	Zone 4	26.5	18.14	68.42	20.40	76.9
Block 2	Zone 1	52.4	52.36	100.00	32.28	61.6
Block 3	Zone 1	56.1	56.12	100.00	36.67	65.3
Total		502.0	390.43	77.78	391.41	78.0

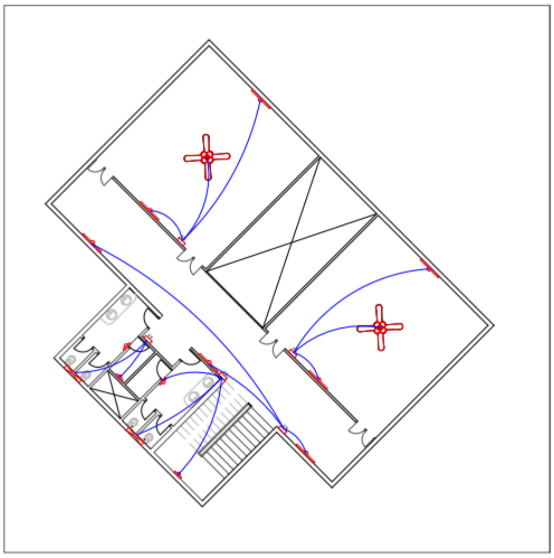
Fig 25. Efficient lighting simulation analysis



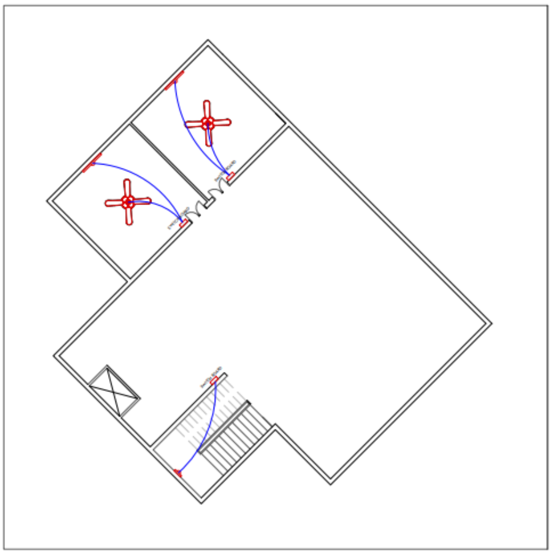
Energy-efficient light placement was obtained after efficient lighting simulation. The following image shows the dayligthing results obtained: The regions that showcase dark blue colour indicate the regions where less natural light is reaching. For the regions where light colours are present sufficient natural light is reaching.

Fig 26. Daylight analysis results

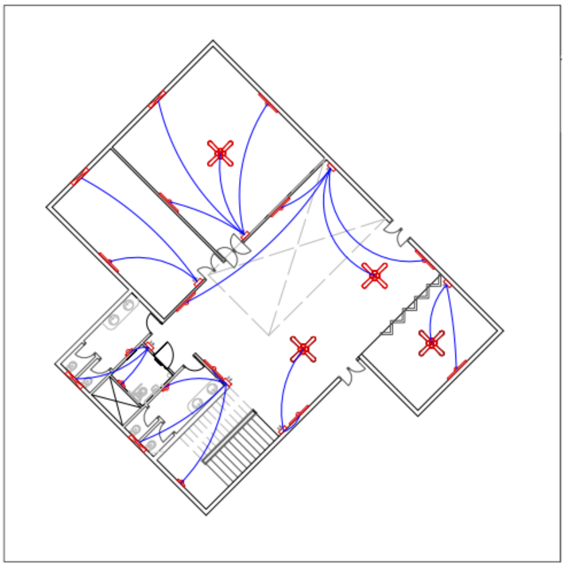
The electrical layout which showcases the placement of electrical appliances in accordance with the lighting simulations is shown below:



REFLECTED CEILING PLAN FIRST FLOOR



REFLECTED CEILING PLAN TERRACE LEVEL



REFLECTED CEILING PLAN STILT LEVEL

Fig 27. Placement of electrical appliances

The building orientation is in sync with the weather conditions which provides natural ventilation. This eliminates the need of using any External HVAC systems.

Increasing Energy Generation

Since the Golaghat site provides a great potential for harvesting solar energy that can further be utilized for commercial as well as domestic purposes, the main aim was to make it much more efficient to capture solar energy. Annual energy consumption is 3650 kWh and the annual energy production is around 3902.5 kWh thereby making our building energy-efficient.

So to maximize the solar energy harvesting system, took the following measures:

1. Selected Passivated Emitter and Rear Cell (PERC) panels are used as solar panels. This is a relatively new technology that adds a passivation layer to the rear surface of the cell that enhances efficiency. It reflects light into the cell, increasing the amount of solar radiation that gets absorbed. Since our site has a limited area and the major challenge is to find out the area for building up the solar energy harvesting system, PERC panels allow greater solar energy collection in a smaller physical footprint, which makes them ideal for limited space. They are only 1.6 % more expensive to produce than traditional panels, due to the added materials needed, but they can be manufactured on the same equipment and can end up having a lower average cost per watt due to their efficiency. PERC solar panels excel particularly well in both high-heat environments and low-light environments, with about a 3% increase in inefficiency.

2. To maximize the solar energy being harvested, we made use of the maximum power point tracking algorithm. Used the incremental conductance algorithm among the several MPPT algorithms available which had many advantages. This algorithm helps to capture the point of maximum Solar Energy available. At the same time, it prevents the oscillation in power which is evident in the case when we use solar panels with no or some other form of MPPT algorithm applied. It has an added advantage that while the traditional incremental conductance algorithm makes a judgment on the position of the system operating point, the improved incremental conductance algorithm makes a judgment based on the directions of power voltage and current

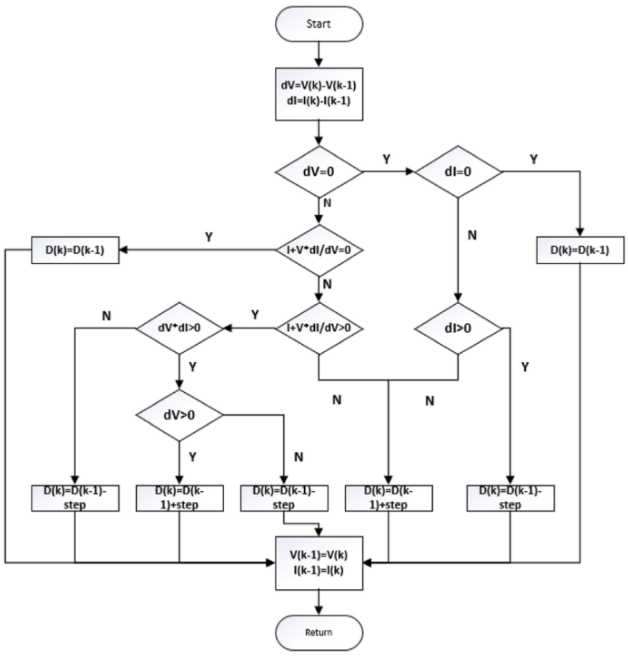


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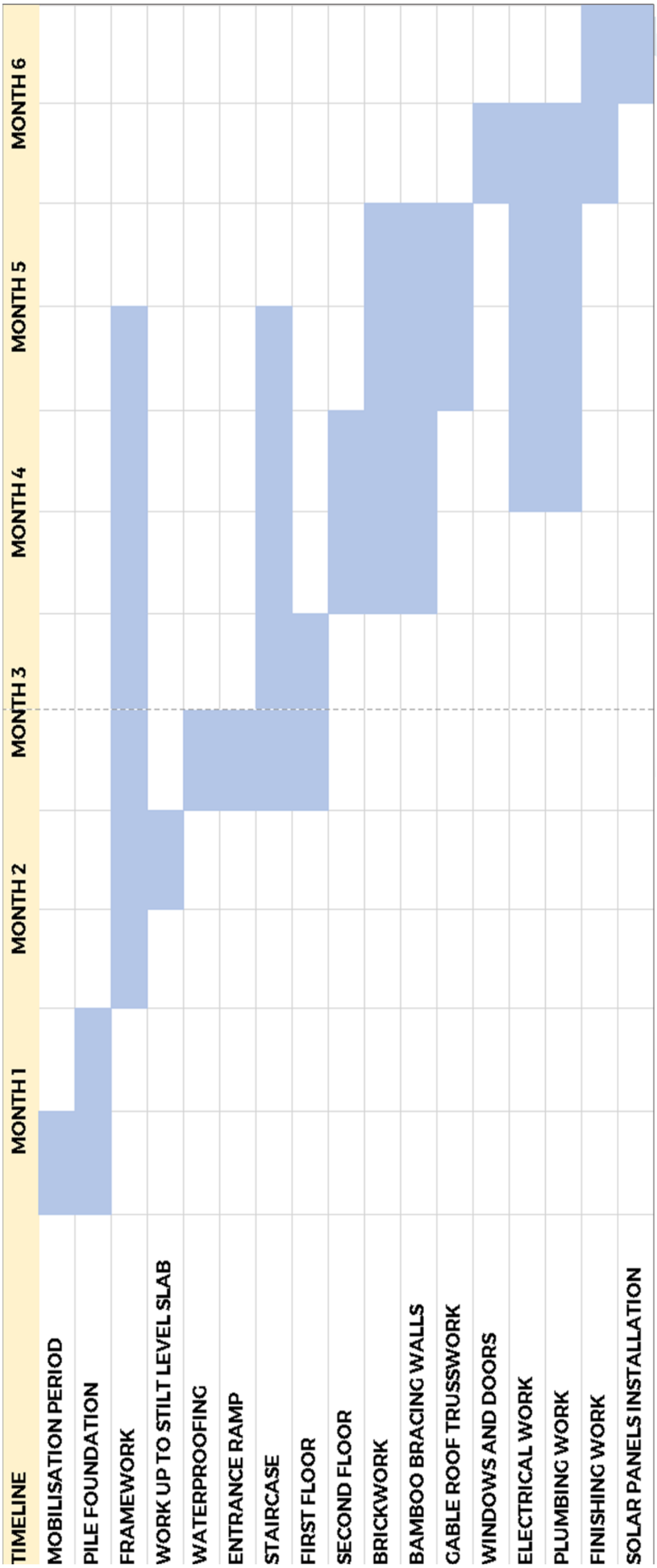
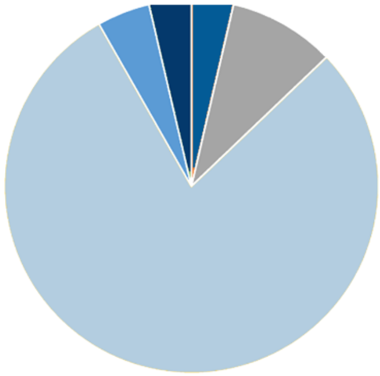
Fig 28. MPPT Algorithm

AFFORDABILITY



TENTATIVE ESTIMATED COST OF PROJECT



Civil cost	₹37,87,547
Water cost	₹4,43,000
Solar panels	₹1,73,179
Equipment	₹1,75,000
Contingencies	₹2,20,226

Tentative total cost of project excluding labour cost. ₹47,98,952

Choice of construction materials:

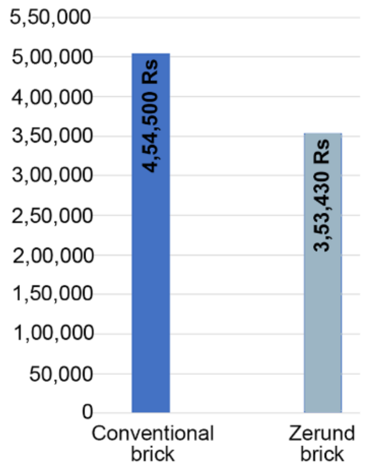
- 80% of our walls are made up of bamboo.
- Locally available materials opted to reduce the transportation cost.

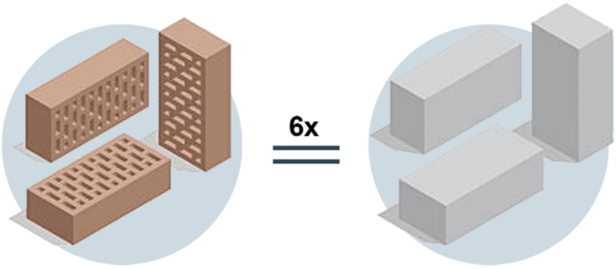
Design Strategies:

- Service core (stairs and toilets) designed at a designated place reduces additional expenditure on plumbing cost.
- Minimum cost on excavation on selection of pile foundation.
- Multifunctional use of spaces like dormitories and community hall.
- Reduced construction time due to use of bamboo wall component.

Fig 29. CRS construction timeline

CIVIL COSTS





CONVENTIONAL BRICK

ZERUND BRICK

With the use of plastic augments in zerund brick:

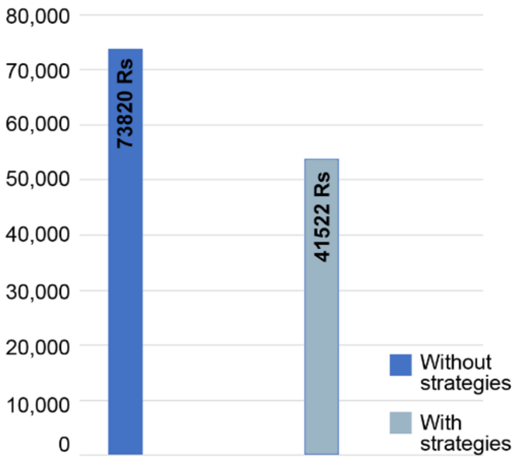
1.The tensile strength of the bricks is enhanced.

2.More resistance towards water absorption hence suitable in times of floods, dismantling any possibility of dampness in the constructions.

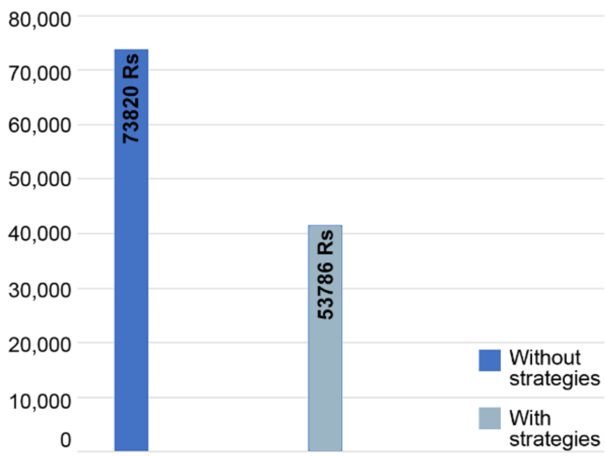
3. One Zerund brick is 6 times that of conventional brick in size hence cost effective. (15-20% lower cost)

WATER CONSUMPTION

Case1: Considering efficient fixtures cost for municipal water supply would be:

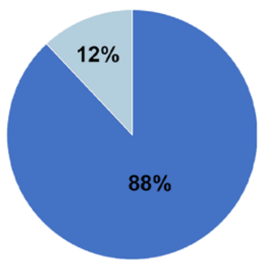


Case2: Considering grey water treatment mechanism cost for municipal water supply would be:

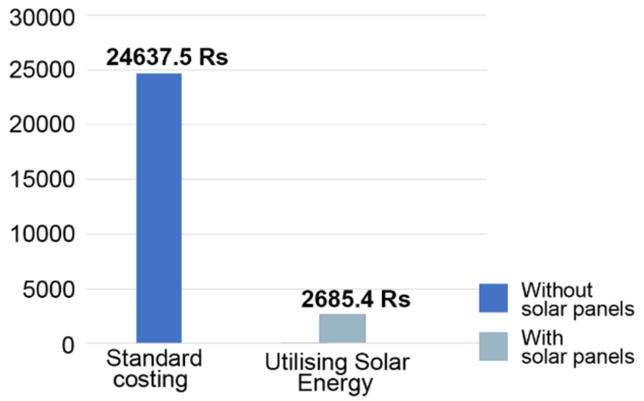


ELECTRICITY CONSUMPTION

- Nearly 88% of our electricity demands can be catered through solar panels itself.
- With 12% reliability on grid source.



STANDARD VS PROPOSED



YEARLY CONSUMPTION AND GENERATION

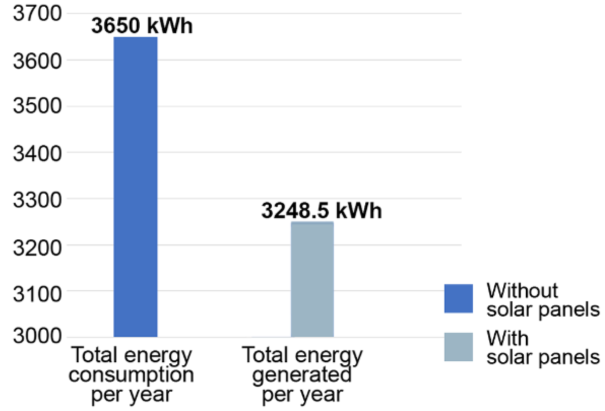


Fig 30. Strategy effectiveness evaluations

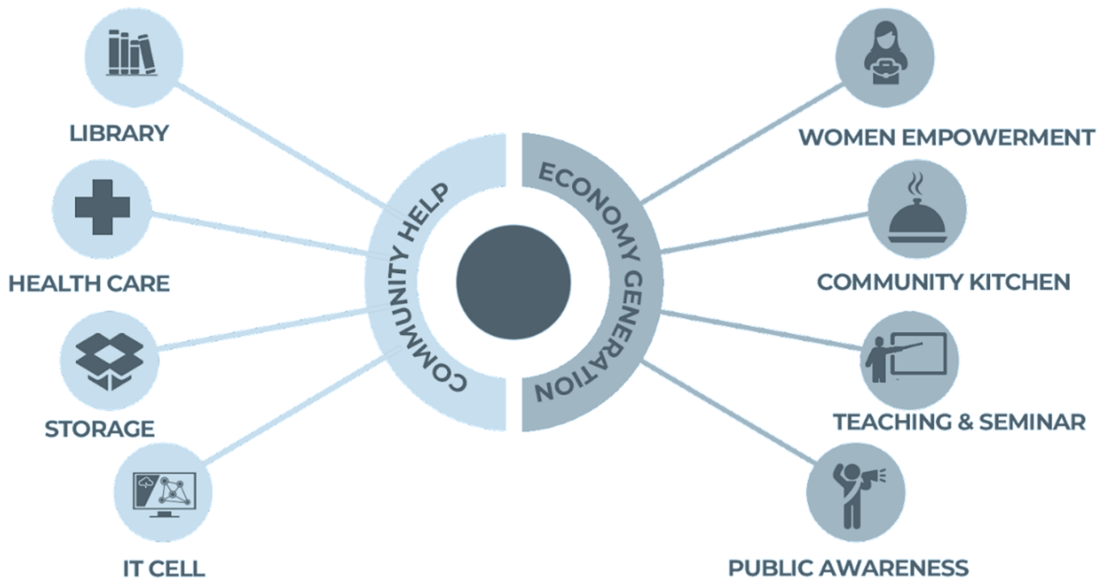


Fig 31. Aid and Services provided by CRS

- Brahmaputra valley of North East India are exposed to *multiple hazards* of seismic, flood and cyclone. During floods, the impact is such that people usually migrate to other places which may not be very hygienic because of the high concentration of people in a limited number of areas.
- According to the statistics, *76% of peopl*e in the surrounding village *do not have a 'pakka house'.* These non-structural houses easily get carried away and do not provide shelter during disasters.
- A community resilience structure has been provided to vulnerable citizens at the time of disaster in Nikori village. During non-disaster times it acts as a self-sustaining model to generate economy, provide employment and multi-facilitated activities.
- Our structure will suffice the needs of the local people of a library, community hall, IT centre, healthcare facility which they lack otherwise.

- **Ease of maintenance** -.Bamboo is a sustainable material and using it instead of RCC cuts down the construction time and carbon footprint. Bamboo being a local material is readily available and this will cut down on the transport cost and in turn reduces the project cost. Bamboo and mud rendered walls will set a permanent local demand-supply chain which is extremely beneficial for the development of remote rural areas.

- **Ease of replication** - The structure is designed such it can be replicated according to the local needs

- **Using local technology** (Zerund Bricks) -

    1. Saves 50% of weight
    2. Less water absorption
    3. More Earthquake resistant
    4. Reduces heating and air conditioning by 30%
    5. Can withstand 6-7 hours of direct fire exposure
    6. Reduces 148 kg of CO_2 for our shelter as calculated compared to conventional red kiln bricks.

- **Center for development** - It can collaborate with various government schemes like

1. *NEEDS*(NGO in Assam) - Space for them to conduct awareness programs to increase market lineage.
2. Modular Health care centres can be a part of *Atal Amrit Abhiyan* as a centre to carry out cash-free health insurance services pre and post floods
3. The centre can align with the Assam government scheme - *Swanirbhar Nari.* Provide women's space, Community hall and kitchen to generate revenue during non-disaster times and improve their standard of living.

Fig 32. UN Sustainable Development Goals implemented

INNOVATIONS

Designing

- Designing dynamic, adaptable, and efficient multipurpose buildings which can be used at all times for different community purposes.

Fig 33. Adaptable design

Structures

- Locally available materials like bamboo are used for the construction of the structure.

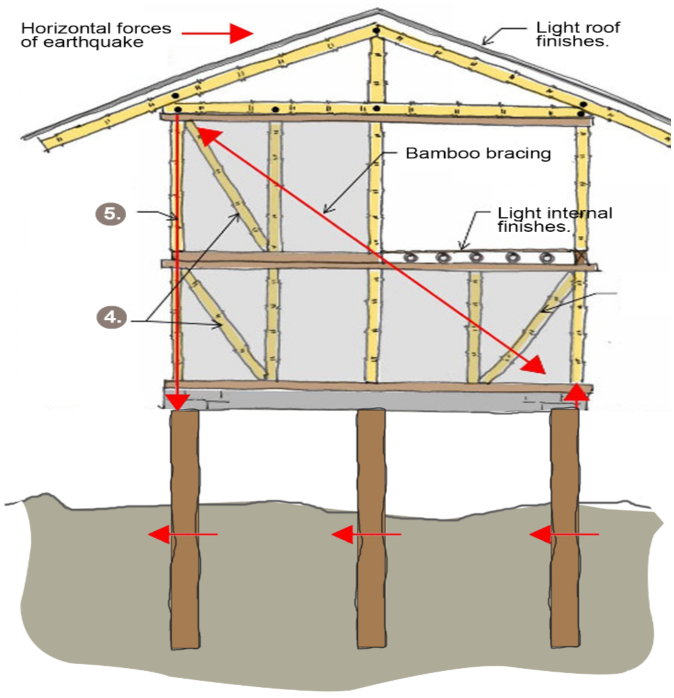


Fig 34. Locally available materials

Water performance

- Gabled roof drains the rainwater to avoid stagnant water and helps in rainwater harvesting.
- Cost-effective greywater treatment using multimedia filter bed and activated carbon filter bed.
- Use of an effective rainy water filter to filter debris from rainwater.

Fig 35. UN Sustainable Design

- Inline check valves to prevent backflow of water.
- Handpumps are provided to use underground water for animal usage.
- Daily consumption is reduced by 30%, using effective fixtures (aerators etc).
- Wet floodproofing is provided.

Energy performance

- Implemented the maximum power point tracking algorithm which helps to enhance our solar harvesting efficiency.
- Made use of the FLOW battery management and storage system which can provide us with a good amount of battery management and battery loss is reduced significantly.

COMMUNICATION

Team Tejasvi decided early on that their main audience would be youth. Since they will lead tomorrow, they must carry the ideologies of net-zero and sustainable development. Hence the best method to spread our work and make an identity would be digital media. Team Tejasvi has used platforms like Instagram and LinkedIn for this purpose.
Our work to promote India’s view on COP26 was also recognized and promoted by the official social media handle of Solar Decathlon India.

Building an Identity

Fig 36. Establishing an audience

Portraying Our Work

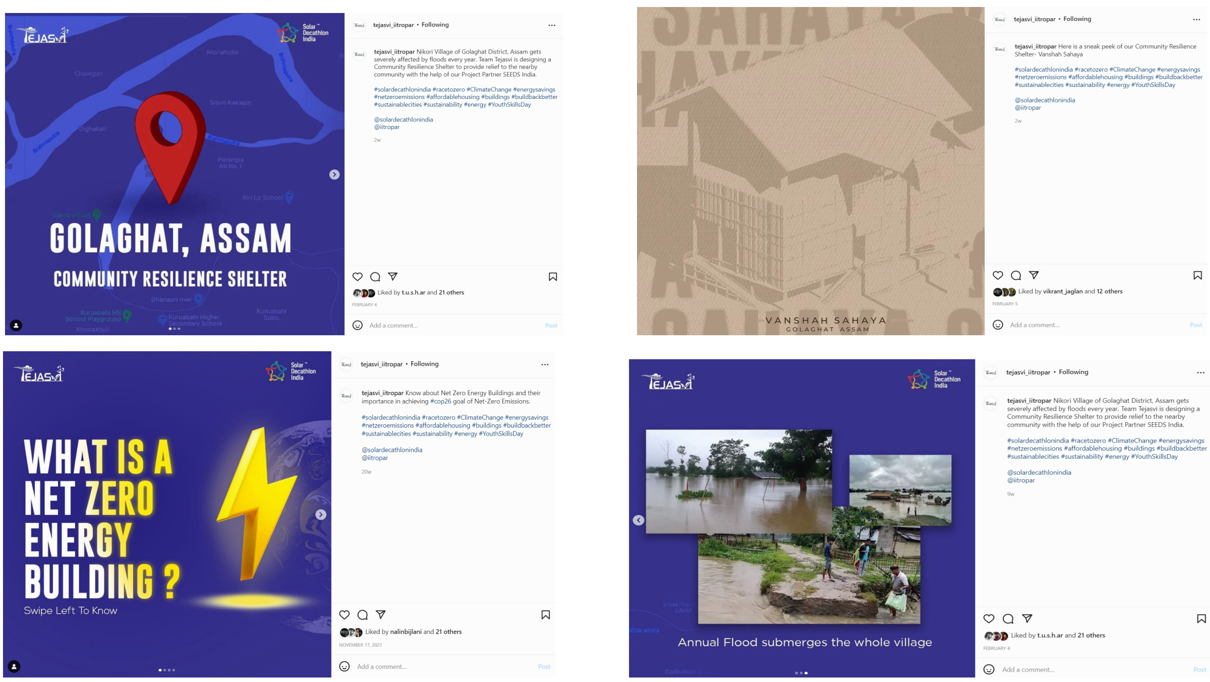


Fig 37. Social Media Presence

COP 26 Highlight

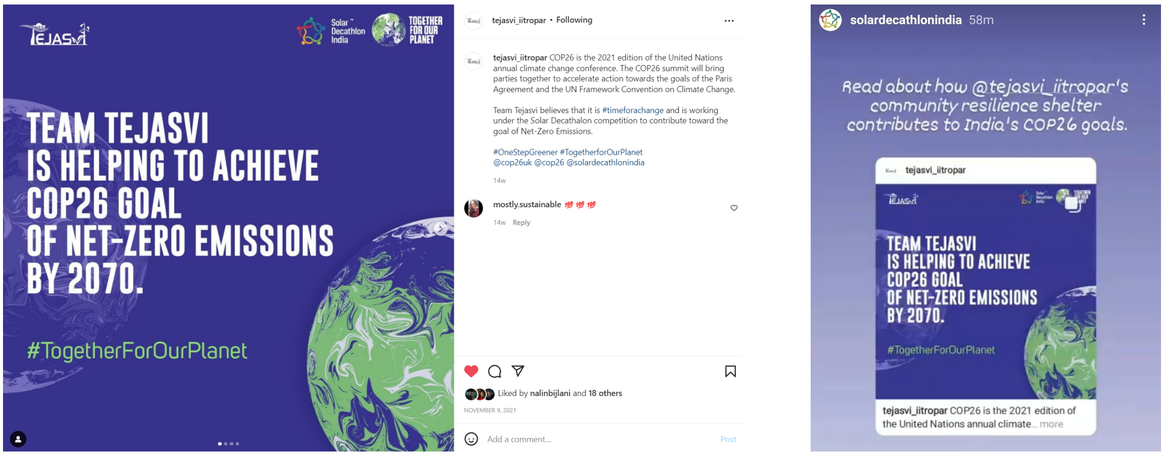


Fig 38. Spreading awareness about net-zero and COP26

Audience Engagement

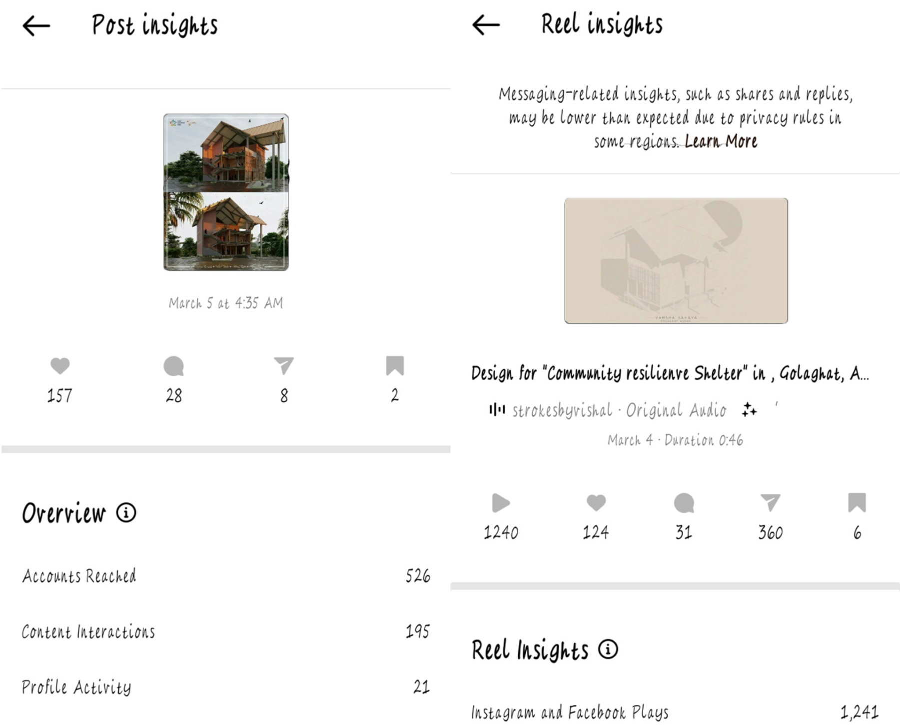


Fig 39. Social Media Insights