VIRYA

MKSSS'S Dr.Bhanuben Nanavati College of Architecture, Pune
STET'S Sinhgad Academy of Engineering Kondhwa, Pune

Community Resilience Shelter

Final Design Report- April 2021

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Executive Summary

The team is a unique blend of aspiring architects and a mechanical engineer across range of age groups- from young minds from the 3rd and 4th year of architectural studies to 5th year students, challenging these ideas with their little field experience. Being like minded people with multiple perspectives but with a singular goal of creating a positive impact on the society beyond the scope of the competition. We are very grateful to this competition for expanding our minds and horizons. We strive to learn something new at each step and deliver with the utmost compassion and sincerity.

Team Virya proposes '**ArkaChitra**' a solution for multipurpose disaster resilient shelters which is net zero, using locally sourced, low carbon materials and which can be customized for a variety of sites. Envisioned as an agricultural resource centre, the building will provide enhanced livelihood opportunities while being a safe refuge during uncertain times and emergencies.

Odisha is exposed to recurring disasters like floods, droughts and tropical cyclones whose frequency and intensity has increased due to erratic weather pattern in the recent years with many cyclones increasingly crossing over the mainland. These cyclonic storms are usually accompanied heavy rains and winds with speeds exceeding 40m/s. (BMTPC, 2010)(Government, 2011) (IIT Kharagpur, September 2006) (India, 2006) (OSDMA, 2009) (Odisha, 2019) (Sheltercluster, September 2018)

Our study led us to an observation that Cyclone Shelters are concentrated around the coastal regions of high-risk damage zone, while remote villages having less than minimum basic infrastructure are affected with recurring loss and late relief operations. The site selected is a tribal village called **Badeguda**, in Mohana Block, Gajapati district, Odisha with a population of 300 falling under 'Moderate to High-Risk Zone with wind speed of 47m/s'.

The Cyclone Shelter is proposed as risk mitigation investment with the following objectives:

- To ensure physical safety of people who have no access to safe shelters
- To save human lives and livestock and to ensure their sustenance during a disaster
- To provide a facility for basic medical relief during and after disaster
- Nodal point for receipt and dissemination of cyclone warnings and carrying out post disaster response and relief activities
- Safekeeping of essential stocks/ items for post disaster usage
- Provides a place for providing basic health services like immunization programmes

The secondary function to be used during regular period is decided based on the consultation with local community. With more than 70 percent of India's population relying on agriculture directly or indirectly, the impact of extreme weather on human life and other living beings is critical. Agro-processing unit, self help group training area with a creche and a multipurpose hall for vocational training and economic advice are planned as a scalable solution to improve the farming-based livelihoods of the target community.

Our proposal is adaptable to different terrains and by using a 6m X 6m design module constructable in a variety of structural systems subject to local availability and skill sets. Designed for the wind speed of 70m/s, the proposal can sustain all types of cyclone winds and having a 1.2m high plinth also withstand coastal tidal surges. The form is decided after thorough wind flow investigations using CFD simulations. Material selection is very carefully done with focus on passive natural strategies and minimizing loads.

Our Team

a. Team: VIRYA

b. Institutions:

1. MKSSS's Dr. Bhanuben Nanavati College of Architecture, Pune
2. STET's Sinhgad Academy of Engineering, Pune

c. Division: Community Resilience Shelter

d. Team Members:

1) Anasuya Nalawade	Student, B. Arch	9) Aishwarya Dalvi	Student, B. Arch
2) Rutuja Badve	Student, B. Arch	10) Aishwarya Patil	Student, B. Arch
3) Vinita Mandole	Student, B. Arch	11) Disha Patel	Student, B. Arch
4) Ayushi Sawalka	Student, B. Arch	12) Sadhana Khade	Student, B. Arch
5) Janhavi Rajwade	Student, B. Arch	13) Sai Suklikar	Student, B. Arch
6) Pratishtha Pandey	Student, B. Arch	14) Sakshi Bhandwale	Student, B. Arch
7) Rutuja Shitole	Student, B. Arch	15) Atharva Mandale	Student,B.E(Mech)
8) Shreya Mandlik	Student, B. Arch		

e. Approach:

We planned to treat the project as a process that is not linear; we visited the project and revisited it with new understanding and better technical base to improve upon the design. We translate our ideas in line with our project partner and industry professionals into a design solution that can positively impact the society. With the intention of protecting communities based on local livelihoods the solution will improve their post-disaster recovery and capacity building will enhance, resilience of the people.

f. Background of the lead institution:

MKSSS's Dr. Bhanuben Nanavati College of Architecture for Women, founded in 1994. The institute is conceived as a multidisciplinary centre of learning where architectural education is considered as a total personality development program. It offers Bachelor of Architecture (B. Arch), Master of Architecture (M. Arch) and Doctorate programs (PhD) under Savitribai Phule Pune University.

g. Faculty Lead

1. Ar. Prajakta Dalal-Kulkarni
2. Ar. Namrata Dhamankar

Faculty Advisors

1. Ar. Nidhi Dixit

h. Industry Partner:

1. Er. Sujata Mehta -Expertise in civil and computer aided structural analysis
2. Ar. Sayali Andhare - Expertise in bamboo structures and vernacular techniques
3. SELCO Technical Team

Project Summary

a. Project Name: ArkaChitra

ReStore | ReBuild |ReShelter

b. Project Partner: SELCO Foundation

SELCO is public charitable trust, aims to create a platform of solutions that uses sustainable energy as a catalyst to link environmental sustainability and poverty alleviation. The interventions of SELCO lead to a sustainable delivery of essential services like housing, livelihoods and health that brings in a holistic development to underserved communities.

Key individual: Ar. Akshatha N,

Built Environment Team, SELCO Foundation

c. Brief description of project and site:

Badeguda, Mohana Block, Gajapati district, Odisha is a remote village located in hilly terrain. The shelter will be kept in readiness for its use as a disaster shelter and maintenance will be carried out by income generating activities. Community involvement in disaster management preparation will be ensured by making it usable during normal times as an agricultural resource center while also reducing the vulnerability by the its secondary use to enhance livelihoods.

Project purpose: Design- Build-Finance-Operate

Project location: Badeguda, Mohana Block, Gajapati, Odisha

Climate zone: Warm and humid

Site Area: 7822.83 sq. m

Odisha

Gajapati District, Mohana Block

Badeguda

Site in Badeguda

d. Context and Market Analysis:

Badeguda is situated in the Mohana Block of the Gajapati district in Odisha. The primary function is as a Cyclone Resilient Shelter based on disaster analysis. The main livelihood is agriculture, hence the secondary function of disaster shelter is Agricultural Resource Center.

e. Special requirements of the Project Partner:

1.The centre to have decentralized sources of renewable energy (needs to be kept off the grid)
2. Use of locally available materials and technologies known to the local people
3.Sustainable design approach with provisions for rainwater harvesting, groundwater recharge and recycling of storm and grey water
4.Proposed shelter to be used as skill development centre for capacity building during regular times and to enhance local livelihoods
5.The centre to be planned for user friendly solutions with optimised storage and living facilities

f. Site Introduction- Context, Existing Service Status and Constraints

- The need for cyclone shelter has been identified based on study of vulnerability of the population and socio-economic condition of the village.
- Badeguda is located in 'Moderate to High-Risk Zone with wind speed of 47m/s' and the inhabitants are tribal population of 300 who practice agriculture.
- Frequent and recurring cyclones affect their livelihoods and their nominal resources to rebuild their kutcha houses decreases the income further.
- The area is not connected with all weather roads as a result communication facilities during flood and cyclone are affected as well as this limits the delivery of the facilities and relief required to the community before, during and post-disaster.
- In this village even facilities of drinking water and electric supply etc. are almost not available and the shelter will have these facilities that can also be utilized during the normal period by the villagers.
- The site selected is at walking distance of 100m from both parts of the village.

g. Area Programme

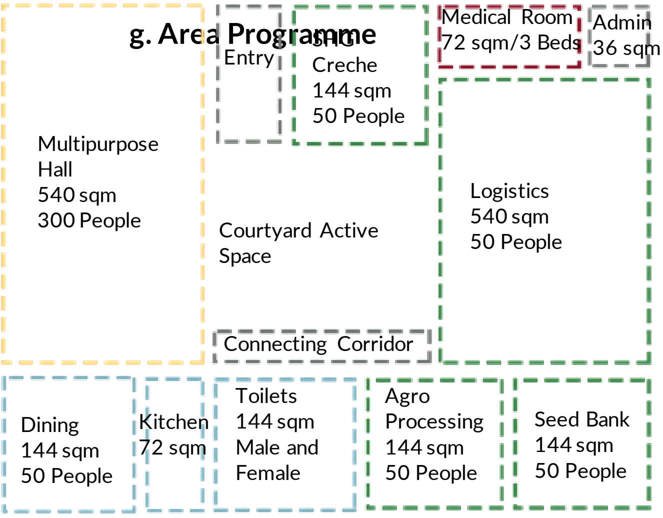


Figure 1- Plan during regular scenario

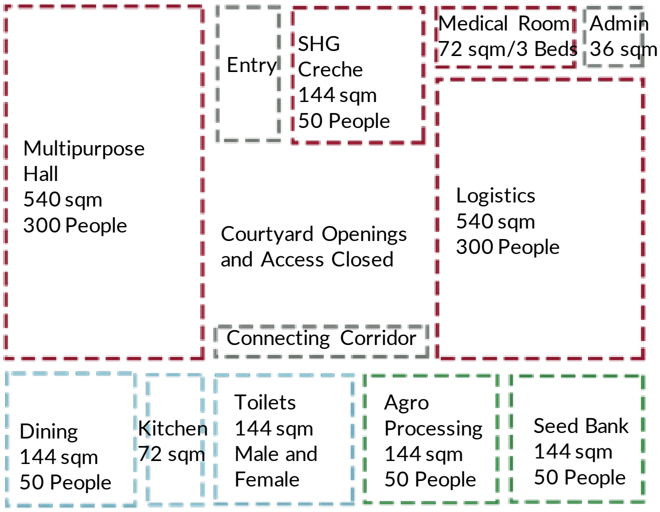


Figure 2- Plan during disaster 'Adapted Spaces'

Primary Use- Cyclone Shelter

Spaces-
- Multipurpose Hall for Habitation
- Toilet Block
- Kitchen and Dining
- Medical Room
- Admin

Secondary Use- Agricultural Resource Center

Spaces-
- SHG and creche
- Logistics that can be converted into habitable space
- Agro Processing Area (For millets)
- Seed bank

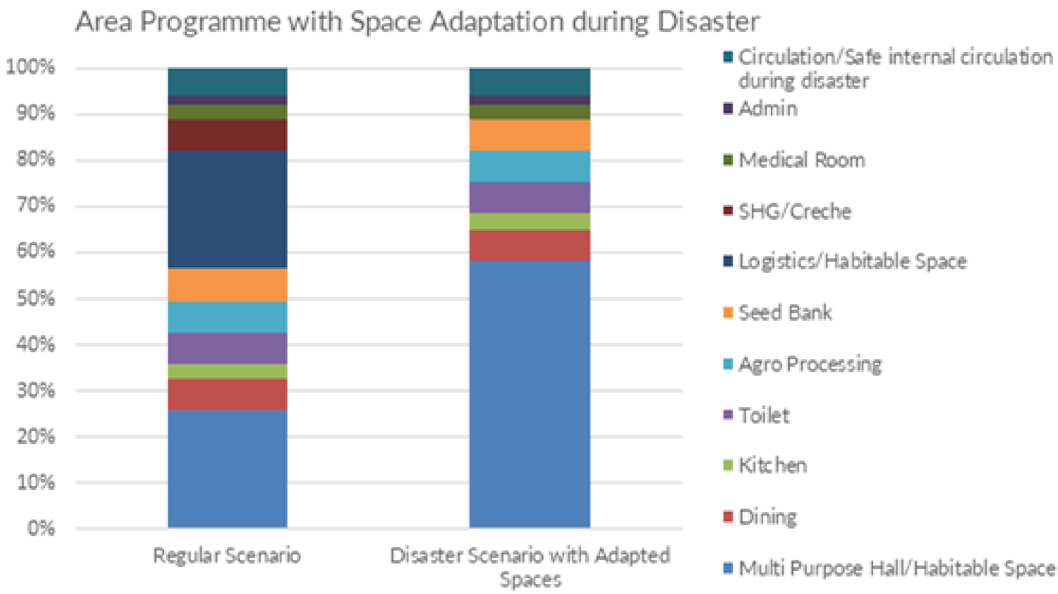


Figure 3- Area programme during regular and disaster time use

Performance Specification

Assembly	Description	U Value	R Value			
Wall	75 Outer Brk wall 80 Air Gap 75 Inner Brk Wall 13 Plaster	1.824	0.548			
Roof	25 W.P. Steel 25 XPS Polyst. 150 Coir board 25 W.P. Steel	0.207	4.824			
Glazing	ST. G clear 6mm Air Gap 13mm ST. G 3mm	2.699		SHGC = 0.784	DST = 0.745	VLT = 0.819

Table 1 - Performance specifications

- **Climate zone**- Warm and Humid
- **Performance specifications:**

i. Envelope (U-value, VLT, SHGC)- U value 1.824 W/sqmK, VLT 0.817, SHGC 0.784

ii. HVAC (system type, CoP, ISEER/EER, Star-rating)- None

iii. Lighting (LPD)- 6/sqm

iv. Electrical (EPD)- 2 W/sqm

v. Renewable energy (system type, generation capacity)- Solar PV,

The following system design is used to meet all the energy requirements on site along with 20 number of 200Ah solar batteries to cater to additional needs during times of disaster.
Solar Panel: 9 kWp (300 Wp, 24 V, 30 Nos)
Solar Battery: 200 Ah, 12V, 20 Nos
Solar Inverter: 10 kW, 120 V

vi. Water systems- Rain water harvesting system, Reed bed

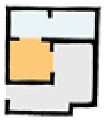
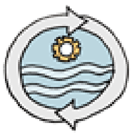
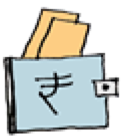
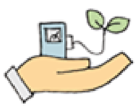
Goals			Achievements
	**Local Capacity Building**	Replicability and rebuilding using local material and construction techniques	Providing Agro-processing unit for conducting training programs.
	**Net Positive Building**	Solar system design by reducing the loads using Energy Conservation Measures (ECMS)	Target energy use intensity of XYZ with net zero energy design
	**Flexible Design for Multipurpose spaces**	Alternative use of spaces during non-disaster period	Primary use as Disaster shelter and secondary use as Agricultural Resource Center
	**Sustainable Site Management**	Employing rainwater harvesting techniques and landscape strategies using native species	Rainwater harvesting potential : 22% enhance more than existing site conditions
	**Thermal Comfort**	Conditions during maximum habitable hours through climate responsive architecture	60% comfort hours achieved with only the envelope design
	**Optimum Water Performance**	Minimizing water consumption on site and grey water recycling for secondary activities	45% grey water recycling out of total water consumed
	**Resilience**	Responsive building orientation and form design	The design withstand against supercyclone with 70m/s and floods due to higher plinth
	**Affordability for Cost Optimization**	Maximising the use of local construction material to ensure the engagement of people and to reduce the cost	Cost effective design considering site constraints and strategic planning
	**Scalability**	Prototype, module based design with	The design will be prototype for 12 villages of newly establishes gram panchayat
	**Enhancement of livelihood and Psychological Comfort**	Promoting self-reliance for economic recovery and providing spaces with flexible individual privacy	Providing Self Help Group (SHG) and woman only spaces and universal access spaces

Table 2 - Goals

Documentation of Design Process

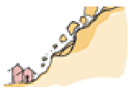
Context Study

Lack of knowledge of agricultural practices has decreased the scope of development in agricultural sector.

Women being large part of population of the village have important status in the society

The village lacks amenities such as medical facilities, knowledge centres, skill development cents etc.

The region although being receiving optimum rainfall, runs out of potable water.

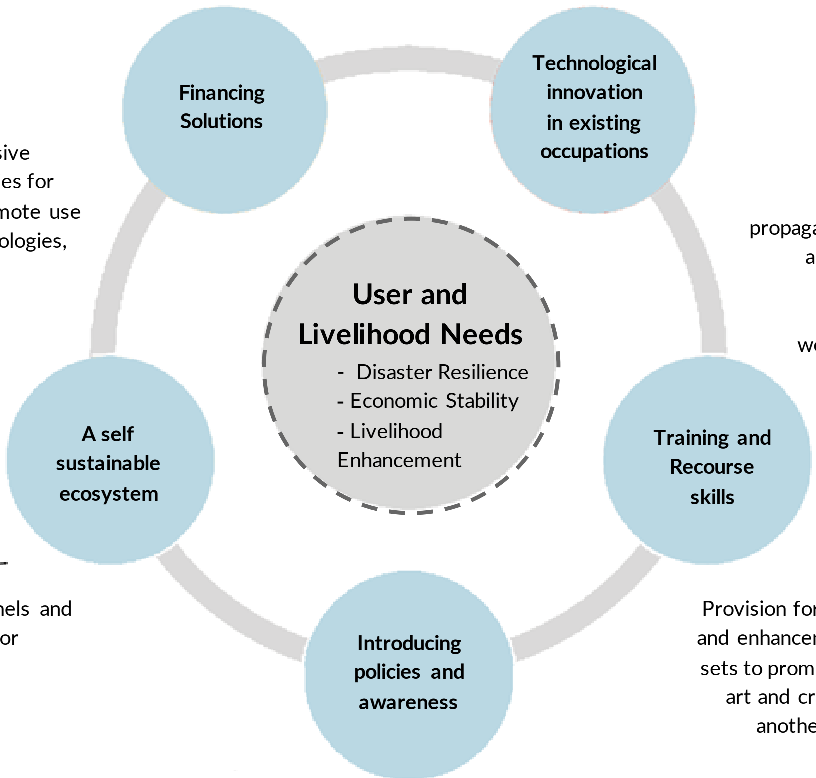


Risk of landslides is a big challenge.

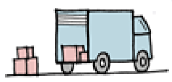
Frequent storm and cyclone.

Concept

Developing inclusive financing strategies for habitats that promote use of efficient technologies, construction and materials.



Identification and promotion and propagation of sustainable and energy efficient innovations and technologies for wellbeing, saving and productive use



Developing channels and market linkages for energy efficient construction.

Provision for new opportunities and enhancements existing skill sets to promote the community art and craft. Giving the user another source of income

Conductive policies for energy efficient building construction.

Figure 4 - Concept deriving from pre-study

Ideas

1. Conservation of the local architecture through use of materials such as bamboo, mud blocks, etc.
2. Special provision to uplift the native crop i.e. millet harvest of the region.
3. Demonstration farms to experiment and innovate techniques of farming in order to achieve maximum produce.
4. Eco efficient techniques to reuse water and returning it back to the primary source.
5. A seed bank that stores seeds to preserve genetic diversity.

Form

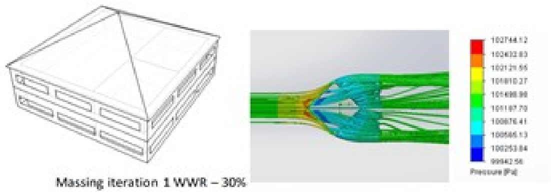


Figure 5- Design Stage 01

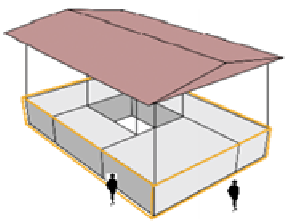
Considering the main design parameters **Scalability and Monolithic modularity**, team decided to go ahead with rectangular planning among hexagonal and circular planning.

Passive Strategies Identified

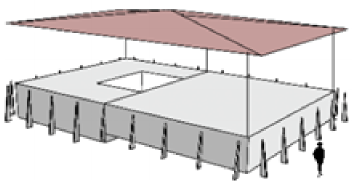
1. Long narrow buildings can help maximise cross ventilation
2. To facilitate cross ventilation, locate openings in opposite sides and larger openings upwind
3. Use plant materials on West to reduce heat gain
4. Minimize West facing facades to reduce heat gain
5. Use light coloured building materials to minimize conducted heat gain

Challenges and Solutions

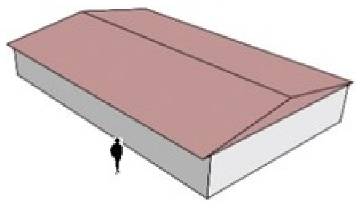
Challenge : The center had to be under one roof considering privacy of user
Approach : Zoning and level variations
Solution : Grid Planning and segregation of activities. Planning in two levels one for habitation and another for Agro-activities



On basis of grid planning, the spaces were planned in a bounding rectangle such that no offsets are created on the exterior facade as these offsets act as wind sucking pocket.



Total building mass was split into two levels in order to mitigate the contours and strategically plan spaces according to the usage.



The hipped roof being the best in terms of reducing cyclonic wind loads, was chosen to make the structure more resilient to cyclonic winds.

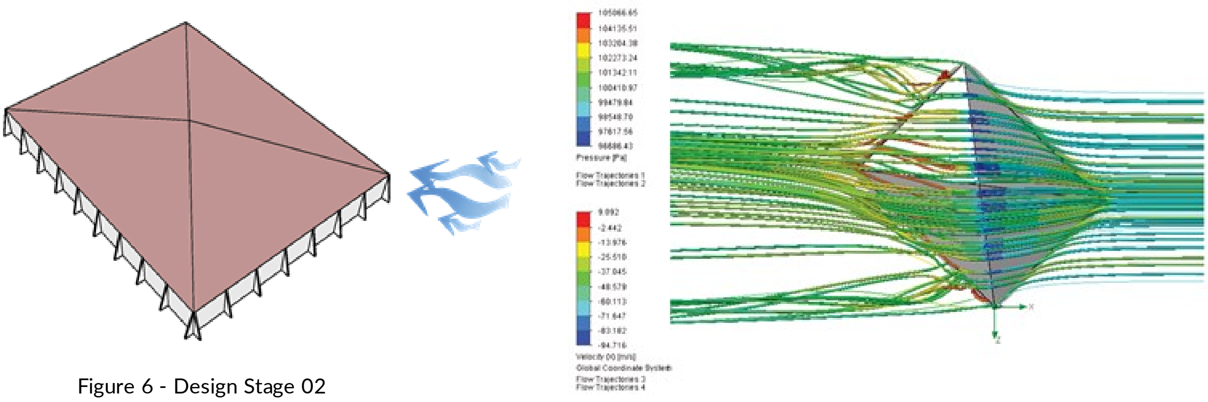


Figure 6 - Design Stage 02

Pros

1. Good wind flow around the building with minimum wake
2. Pressure evenly distributed over the surface

Cons

1. Lack of desirable level of light and ventilation

Challenges and Alternative Solutions

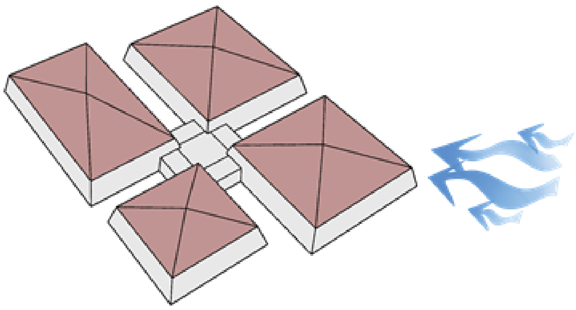
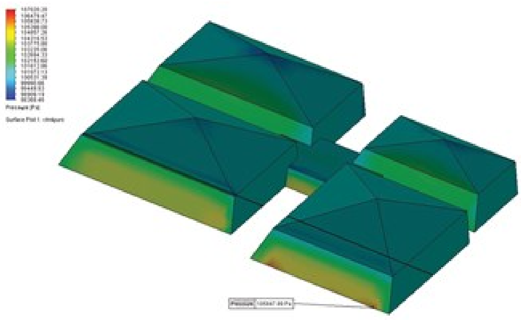


Figure 7 - Design stage 02 (Alternative 01)



Surface Pressure Plot

Challenge : Light and ventilation, architectural character (To direct the wind, different approaches for roof have been tried)

Approach 1 : Breaking the spaces in zoning
Solution : Clustered planning
Problem : Internal circulation issue

Pros

1. Wind flow is well managed reduced waked at the exit. The buildings on leeward side are protected from the wind.
2. Skewed walls are better at deflecting the wind up and over towards the roof higher pressure is only observed at the base of walls.

Cons

1. Cross ventilation not effective
2. Central core circulation can cause disorientation during disaster

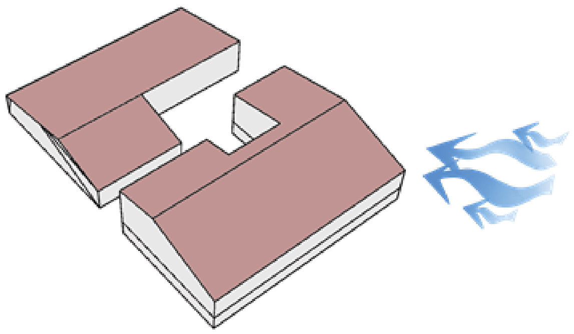
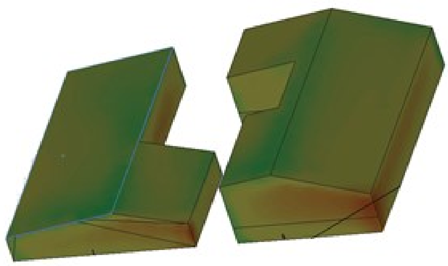
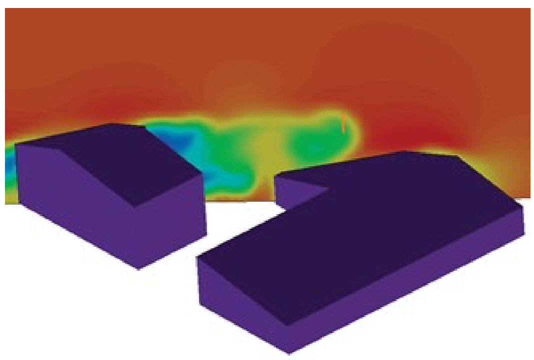


Figure 8 - Design stage 02 (Alternative 02)



Surface Pressure Plot



Cut Plot Wind Velocity

Approach 2 : Introducing courtyard
Solution : Central courtyard with external access
Problem : Wind pressure at the corners of the form

Pros

1. Building on leeward side is protected from the wind
2. Massing is reduced from earlier single overwhelming mass

Cons

1. Wind flow in between two building creates turbulence hence and ventilation outlets in that regions are not possible
2. Air flow around this layout is extremely unpredictable
3. Internal circulation during disaster is not possible due to lack of connection between the masses

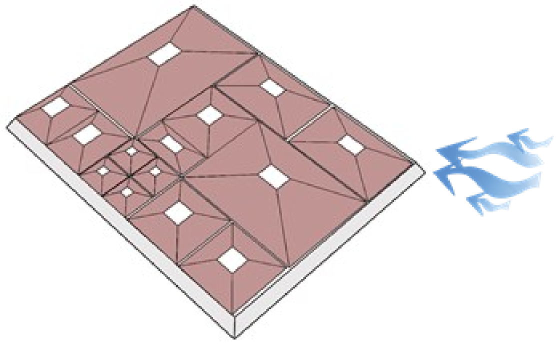
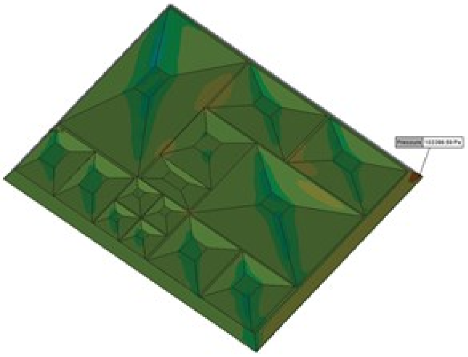


Figure 9 - Design stage 02 (Alternative 03)



Surface Pressure Plot

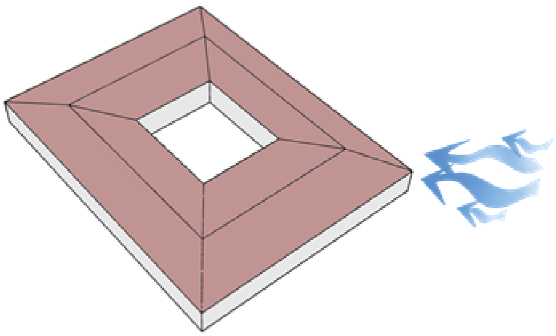
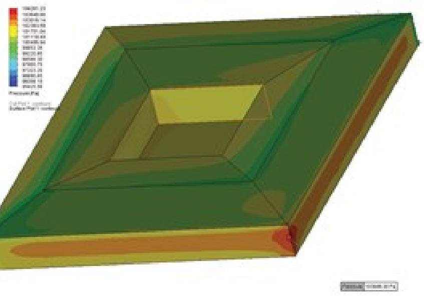


Figure 10 - Design stage 03



Surface Pressure Plot

Challenge : Light and ventilation

Approach 1 : Breaking the roof into small vents
Solution : Pyramidal roof
Problem : Water clogging issue from roof through gutters

Pros

1. Steady flow around the building
2. Good lighting

Cons

1. Complex air flow over the roof
2. Poor Ventilation

Approach 2 : Introducing courtyard
Solution : Central courtyard with internal access for connection during cyclone
Problem : Water in collection in courtyard possible which can be solved with sloped underground channel

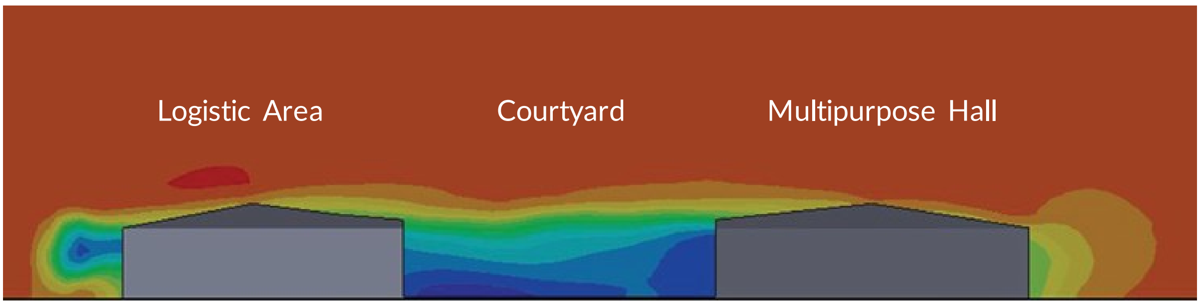
Pros

1. Good wind flow around the building with minimum wake
2. Pressure evenly distributed over the surface
3. Better ventilation, lighting and functional circulation

Cons

1. Turbulence in courtyard area creating low pressure region
2. Courtyard not accessible as all openings into the courtyard will be closed during cyclone

Tools used : Design builder and SimScale



Design Documentation

Architectural Design

Scenario 1: An Agricultural Resource Centre (Regular Case)

'ArkaChitra' is a solution for multipurpose disaster resilient shelters which is net zero, using locally sourced, low carbon materials and which can be customized for a variety of sites. Envisioned as an agricultural resource centre, the building will provide enhanced livelihood opportunities while being a safe refuge during uncertain times and emergencies.

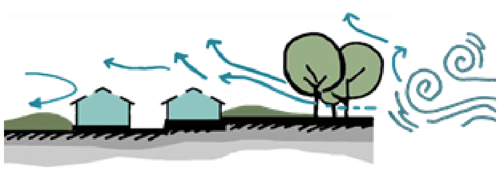
The cyclone shelter is placed along the contours, sloping towards NW. It has 2 separate entrances to avoid cross-circulation

1- Cattle shed
2- Multipurpose Hall + Dining
3- Central Courtyard
4- Agro Processing Unit
5- Logistics
6- SHG Self Help Group

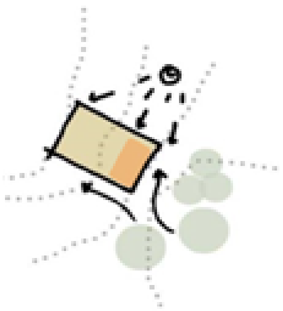
Site Plan

Figure 11 - Site plan Before Disaster

The response to the contours is such that it creates 2 levels by cut and fill method along with a central courtyard. Upper level is an agricultural processing area which also acts as a buffer for lower level, which is a multipurpose hall for training and will act as a shelter during disaster. Level difference between the two will give required height for the hall. 1:10 Ramps are provided for accessibility



The monolithic building form is based on wind simulations, tilted at 45°, to tackle cyclone winds. Orientation is in such a way that we receive maximum natural light from north side, and roof.



1

Cattle Shed
Racks for fodder and water are provided in the shed

2

Multi-purpose Hall
Space for various activities

3

Central Courtyard
Spill-over area of multipurpose hall and logistics

4

SHG and Creche
Combined areas for ease of women working

5

Loading/unloading Zone
Stacking of raw and finished goods

6

Agro-Processing with equipments

Scenario 2: A Disaster Resilient Shelter (Disaster Case)

The Shelter rearranges its spaces to accommodate more people at the time of disaster. Major areas like multi-purpose hall and logistics area are converted into sleeping areas with a capacity upto 600 people. Adjacent areas like agro-processing and seed bank, the equipments will be aligned along the edges and the remaining space to be used to store the luggage and belongings of people. The outer areas and central courtyard are not accessible in case of disaster.

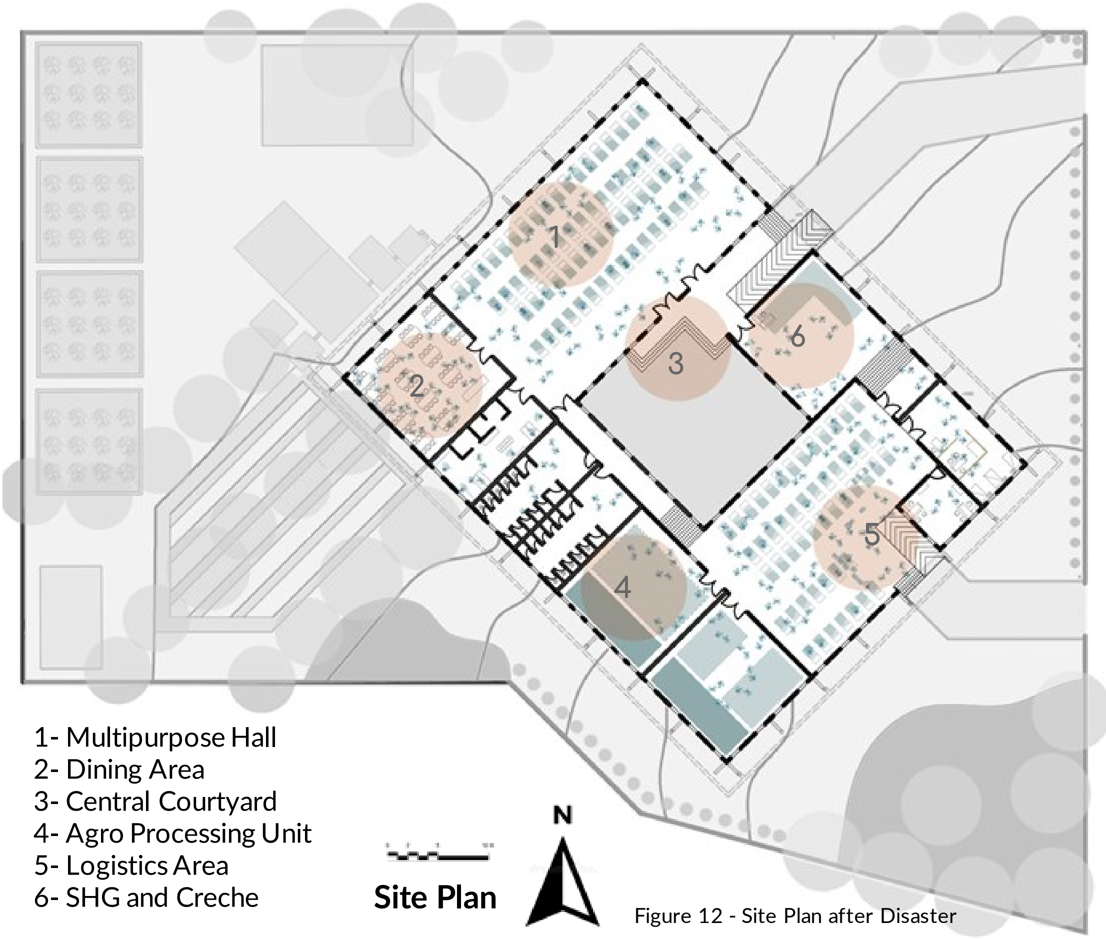
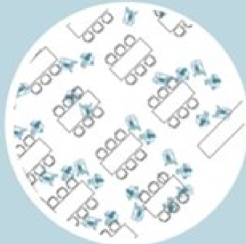


Figure 12 - Site Plan after Disaster

Multi-purpose Hall
Large areas to be used as sleeping spaces



Dining Area
Food serving area in batches for the people

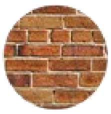
Central Courtyard
Inaccessible during disaster, enclosed to avoid rain and wind

Agro-Processing Unit
Equipments and storage of belongings

Logistics Area
Sleeping area

SHG and Creche
Space for storage of goods and belongings

Materials used:



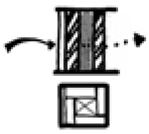
Brick

Bamboo

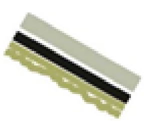
Space Truss

White painted steel sandwich Panels

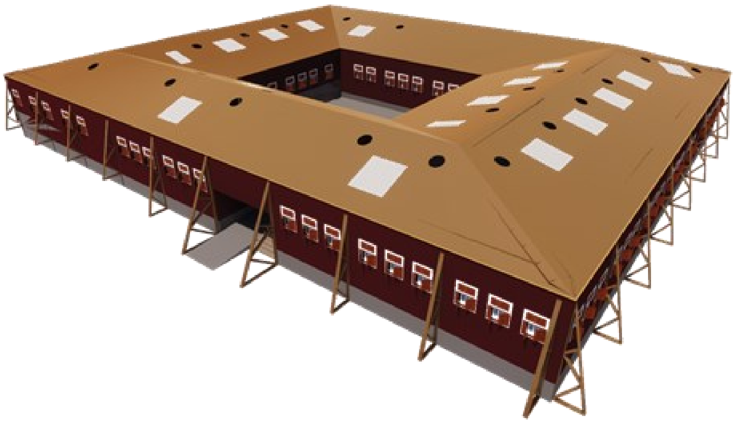
Climate considerations: Thermal comfort- Cross ventilation in every room Stack effect: to remove warm air from upper levels.



Rat trap bond creates cavity which reduces heat gain from walls.



Roof Assembly is such that the panels together form a higher thermal mass. Coir Boards for insulation, white painted steel sheets are locally sourced materials.



ARKACHITRA- Views of Proposed Shelter

Engineering systems in shelter:

Solar powered fans, lights, pumps, and electric grid.

Upper shutter forming chajja when opened.

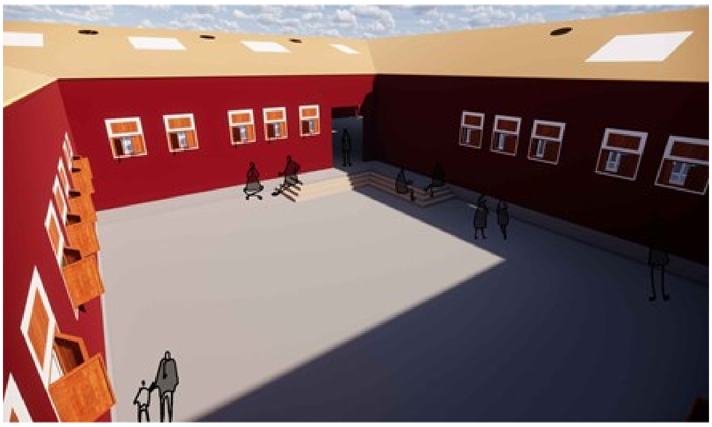
Earth berms and trees at the edges divert cyclone winds. Rainwater from roof and surface runoff is collected at the lowest contour.

Multi-purpose Hall

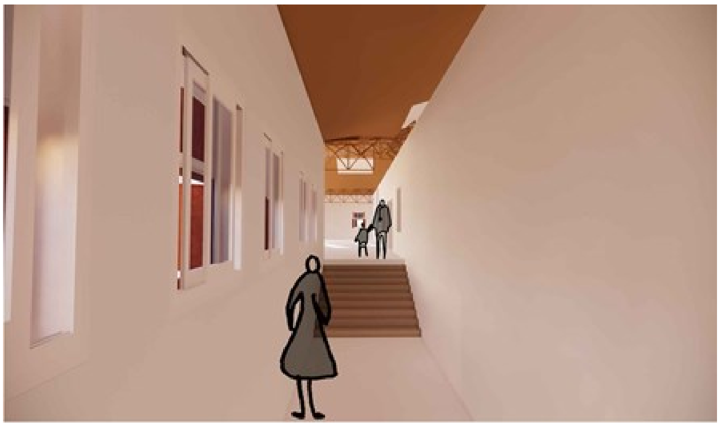
Logistics Area

Dining Area

Self Help Group and Creche



Central Courtyard Space



Corridor connecting Multipurpose Hall and Logistics

Engineering Design and Operations

Load Transfer

Space Truss – Columns & Buttresses – Foundation – Ground

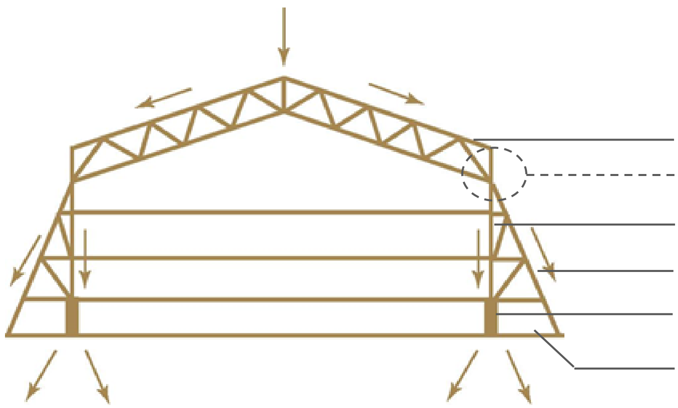


Figure 13: Load transfer through line diagram. The horizontal bands help tie the structure together and reduce slenderness ratio of wall

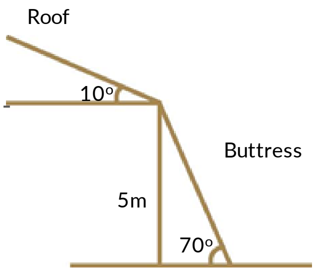


Figure 14 : Defining the angles of roof and buttress used in CFD simulation

Rightsizing Calculations

- Considering Diameter of Bamboo = 75mm
- Compressive Strength of Bamboo = 13 N/mm^2
- Slenderness Ratio to be kept < 80
- Considering longest truss member as 2m L/Rmin = 2000/37.5 = 53.33 < 80 = Safe
- The total load calculated = 8.5 kN
- Load/Area = (8.5) / (3.142 x (37.5)^2) = 1.92 < 13 = Safe

Openings

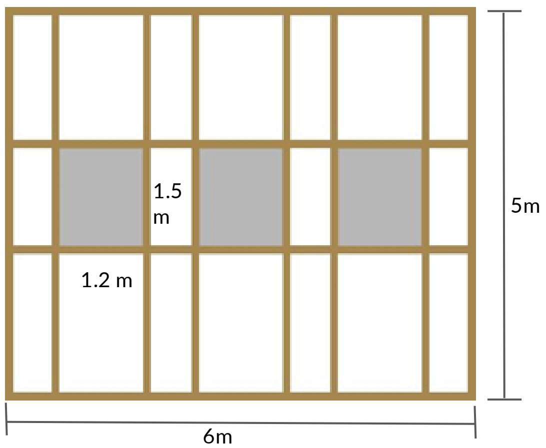


Figure 15: Wall elevation of one bay showing opening sizes and vertical reinforcement positions

- Wall openings should be optimized
- Opening = 20% of wall surface area
- Wall Area = 30 sq m
- 20% of area = 6 sq m
- Window = 1.2 x 1.5 = 1.8
- 3 windows = 3 x 1.8 = 5.4 sq m

- Bamboo Crete bands running along sill, lintel and roof
- Vertical reinforcement running every 1.5m span and along openings
- Cross bracings provided at every 4th bay of 5m x6m wall

Building operation manual for building users

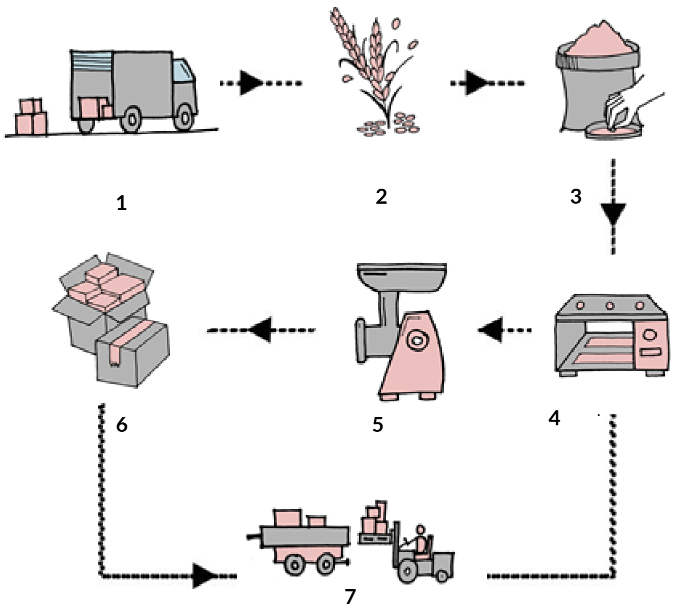


Figure 16 : Agro Processing during normal scenario

OPERATION DURING NORMAL SCENARIO

SHG training, creche, multipurpose hall can be used as flexible spaces for community interactions; Agro-processing is fixed activity

1. Unloading the produce in logistics area
2. Cleaning and grading of grains
3. Proper sorting and stocking
4. Machine drying
5. Grinding
6. Packaging in logistics area
7. Transporting to the nearest local market for sell

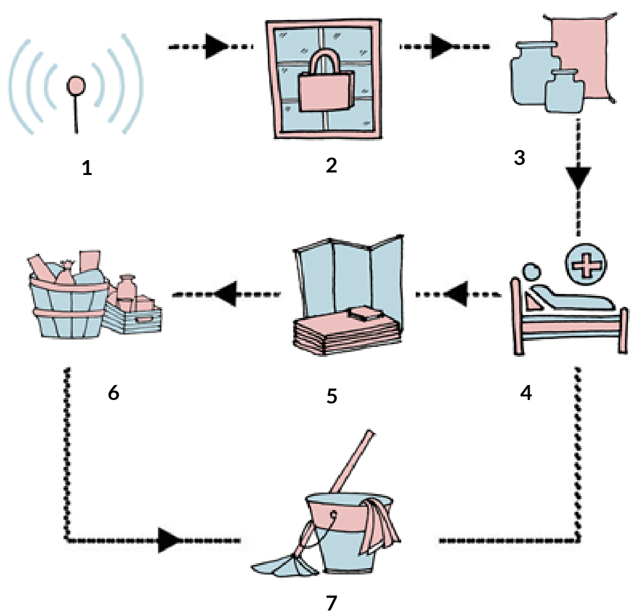


Figure 17: Steps for preparing the center for disaster

PREPARATION STEPS - DISASTER SCENARIO

1. Keeping communication systems on standby for coordinating relief operations
2. Securing all openings and our 'special windows' from inside
3. Stocking community kitchen with supplies
4. Preparing medical unit for post disaster diseases and precautionary vaccines
5. Setting up mattresses and partitions for multipurpose hall use
6. Storing of existing produce effectively for use during or after disaster
7. Clearing out the logistics for additional occupancy

MAINTENANCE SOLUTIONS

1. Checking for damage to the exposed joints near buttresses and gutters
2. Cleaning of the site for maintenance of water harvesting strategies
3. Checking the electrical circuits and agro equipment and their maintenance

MATERIALS USED FOR CONSTRUCTION

1. Bamboo for structural members
2. Bricks as wall material
3. Metal holdfasts for strengthening
4. Timber for windows
5. White painted steel roof sheets with coir board insulation: sandwich panel

Structural System and Details

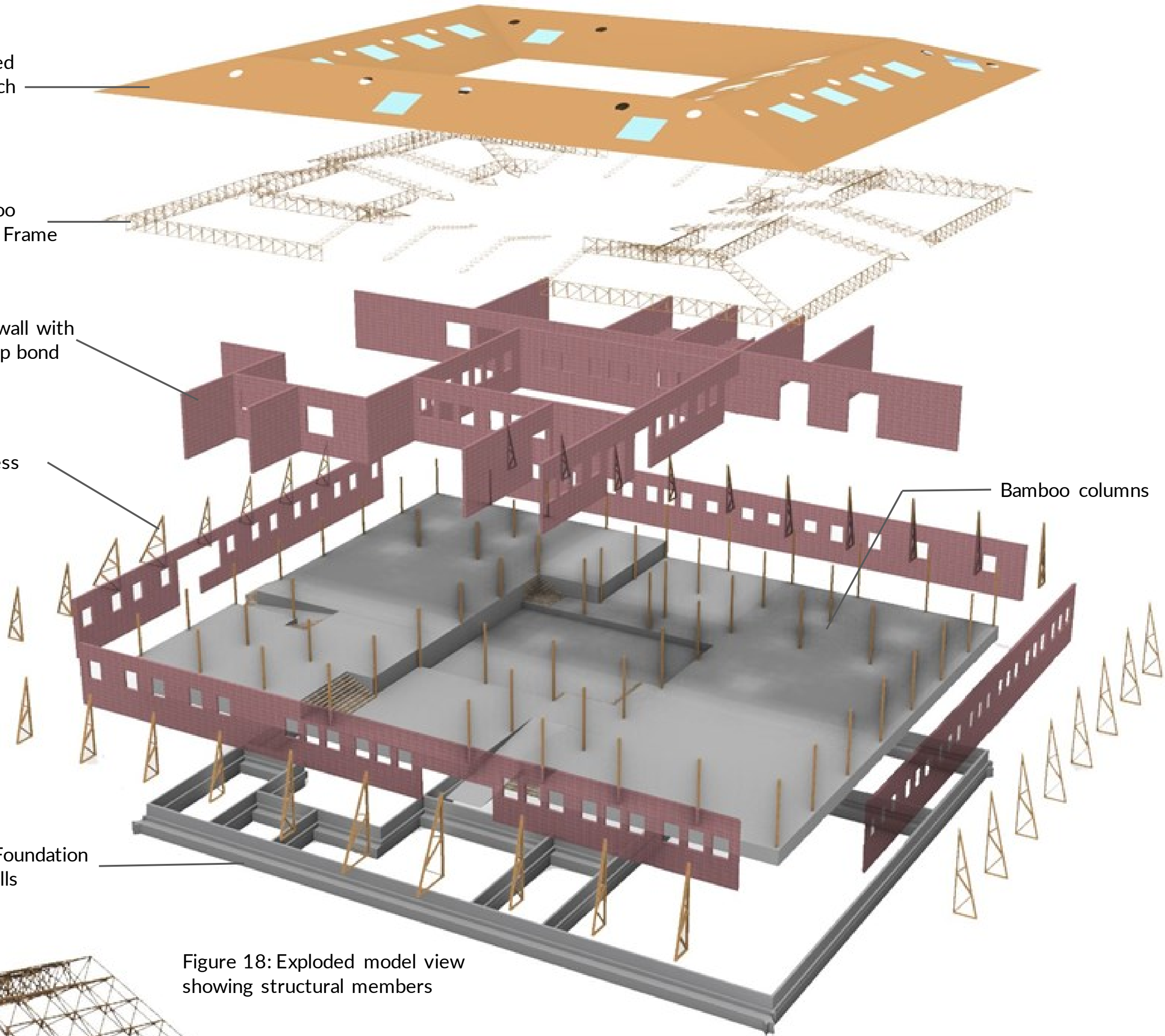


Figure 18: Exploded model view showing structural members

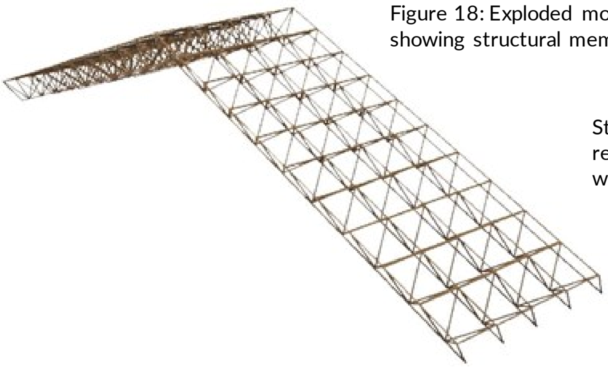


Figure 19: Space frame formation

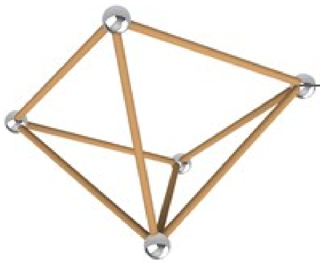


Figure 20: Ball socket joint for truss members

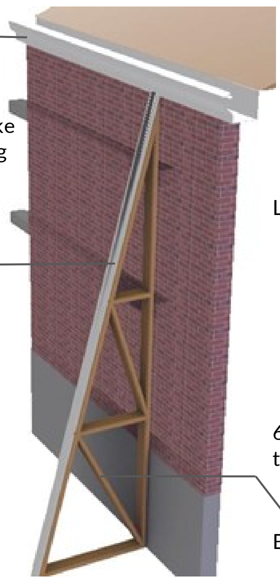


Figure 21: Gutter detail

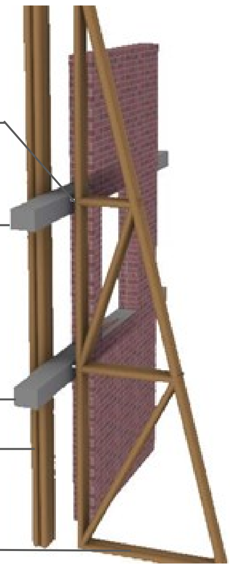
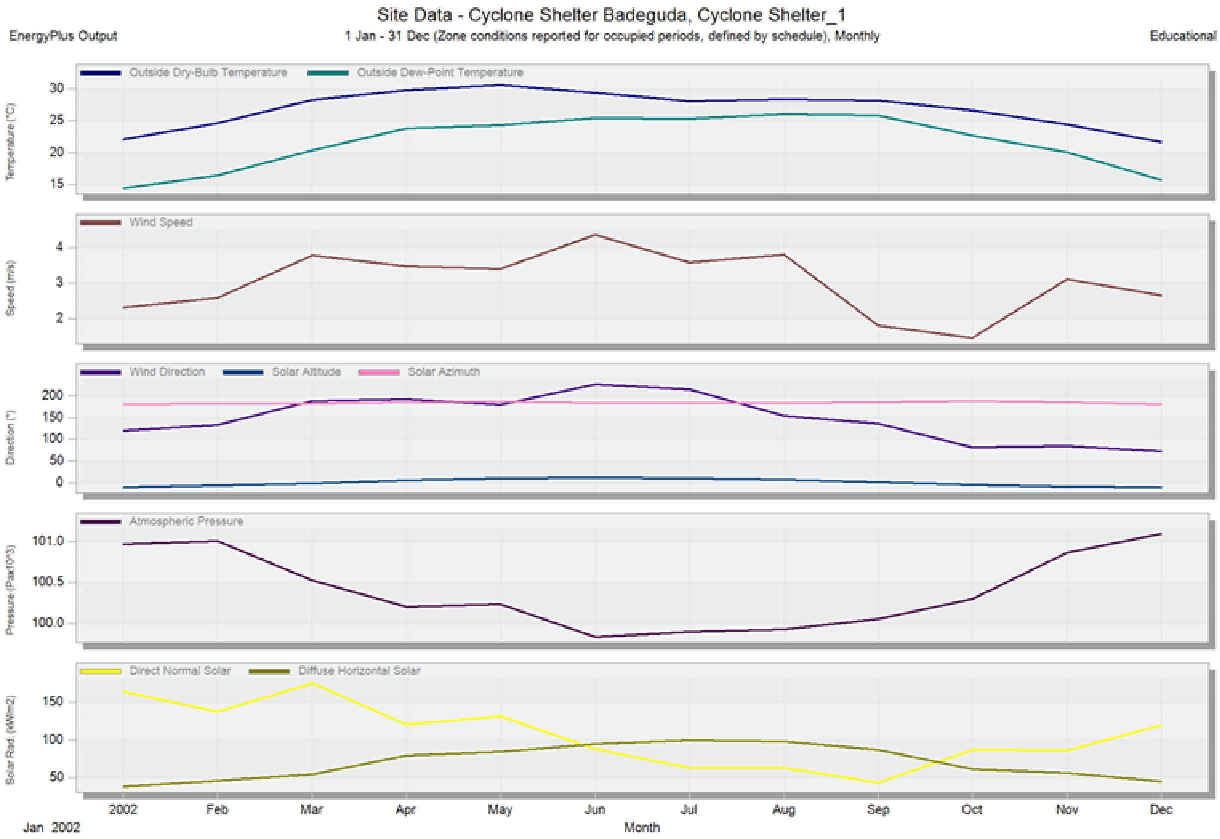


Figure 22: Column to Buttress joinery

Energy Performance



Existing conditions for designing

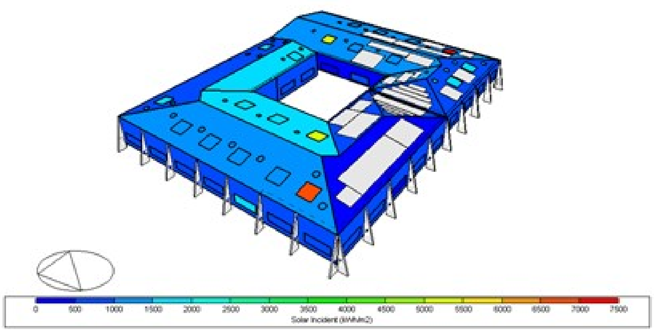
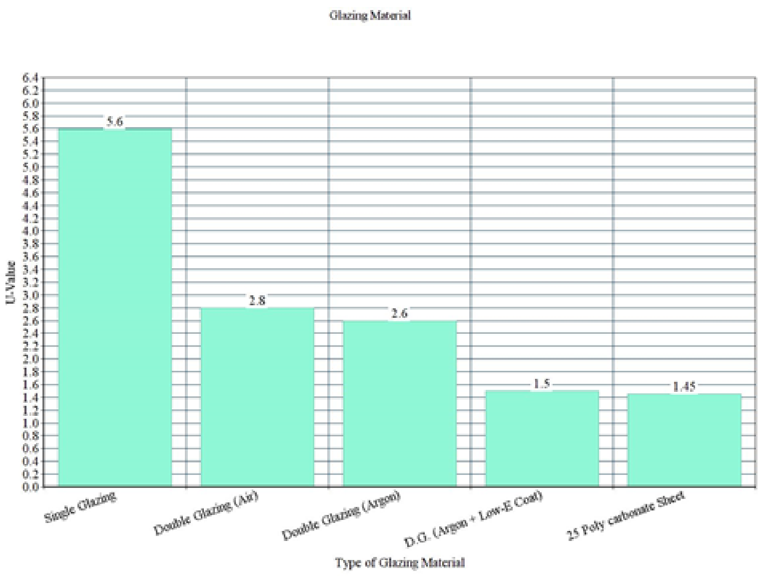


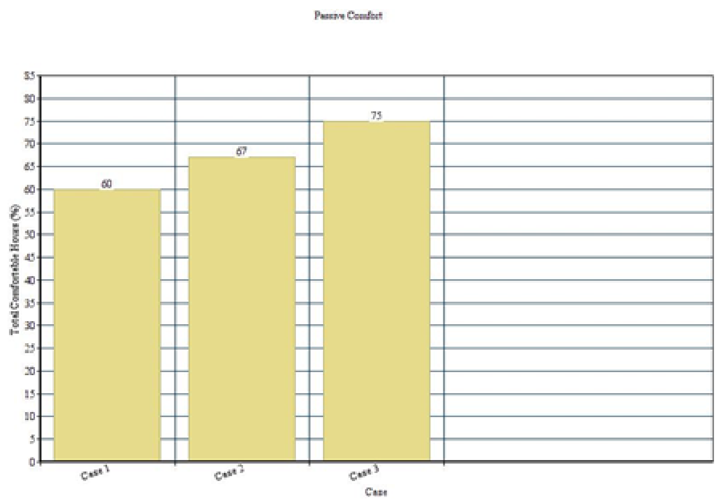
Figure 23 - Solar Irradiance

Design Challenge- Optimizing openings to increase daylight ingress, increase cross ventilation to facilitate comfort in a warm and humid climate and provide efficient protection against winds during cyclone.

The design aims to reduce heat gain through efficient envelope design in order to reduce equipment loads which in turn reduces the internal heat produced by the appliances. Optimum number of lights and fans are decided to ensure maximum comfort balanced with a low EPI, facilitating efficient solar system design to achieve resilience during times of disaster by minimizing power consumption. The reduction in EPI aids the accomplishment of a netzero building with the energy demands fulfilled by the renewable source of solar energy, accompanied by a battery storage system to facilitate convenient and uninterrupted functioning of the building at all times. (Efficiency, 2017)



Material Selection- 25 mm thick Polycarbonate sheet is selected for its lowest U-value for the skylights. It has additional properties such resistance to UV rays, high strength and stiffness with tensile strength of 60N/sqm. It proves to be the most energy efficient and cyclone wind impact resistant material. Double glazing with air gap is taken for window openings considering the factors of cost and availability.



Case 1-
Roof Assembly- 25 GI sheet + 25 Coir pith insulation + 200 air gap + 25 GI sheet
Wall Assembly-75 Outer and internal brick wall 80 Air gap, 13 Plaster, Rat trap bond
No stack vents provided

Case 2-
Roof Assembly- 25 GI sheet + 150 Glass wool Insulation + 25 GI sheet
Wall Assembly- 75 Outer and internal brick wall 80 Air gap, 13 Plaster, Rat trap bond
No stack vents provided

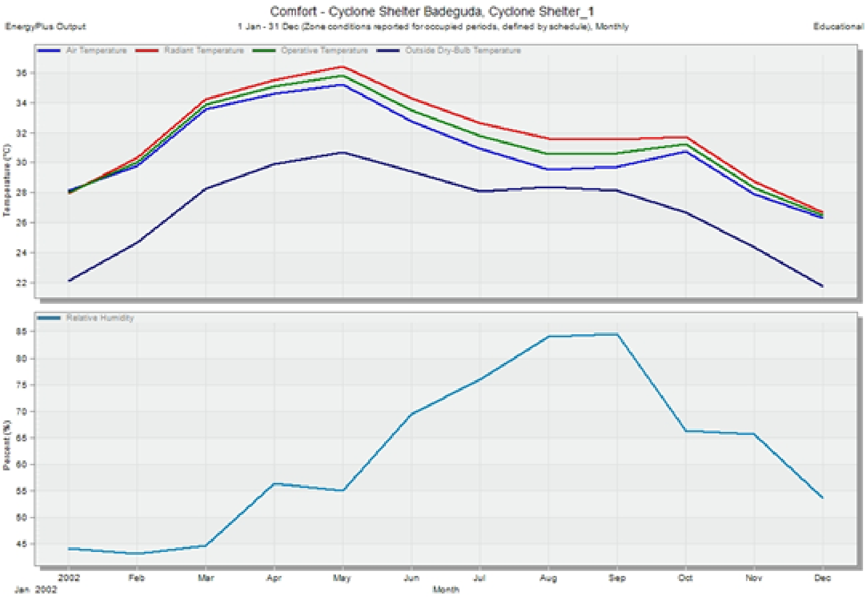
Case 3-
Roof Assembly- 25 White Painted Steel + 25 XPS + 150 Coir pith insulation + 25 White painted steel
Wall Assembly- 75 Outer and internal brick wall 80 Air gap, 13 Plaster, Rat trap bond
Stack vents provided

Appliance	Brand	Power Rating
Ceiling Fan	Havells	26
Extract Fan	Havells	22
LED Bulbs	Wipro	9
LED Battens	Wipro	20
Pumps	Grandfos	1500

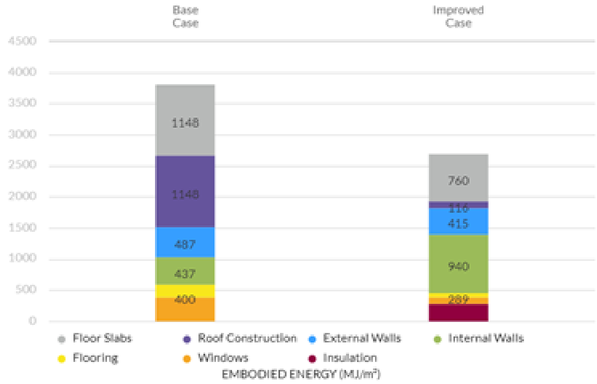
Table 3 - Use of energy efficient appliances to reduce loads

Optimizing solar system design for the period of disaster to attain self-sufficiency.

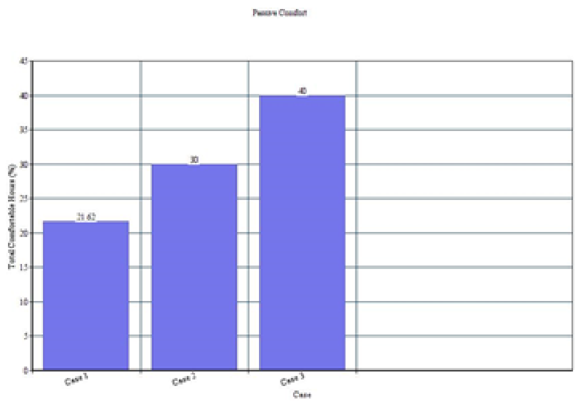
The following system design is used to meet all the energy requirements on site along with 20 number of 200Ah solar batteries to cater to additional needs during times of disaster.
Solar Panel: 9 kWp (300 Wp, 24 V, 30 Nos)
Solar Battery: 200 Ah, 12V, 20 Nos
Solar Inverter: 10 kW, 120 V



Case 3 (Selected Case)- It provides maximum thermal comfort hours. Additional factors considered are- cost, availability of material (local), availability of local labour and community participation. The comfort hours achieved for the case amounts to 6542 in a year, where addition of cyclone resistant roof ventilators to facilitate stack effect adds up to 400 comfort hours in the total amount.



Embodied Energy



40 kWh/ sqm/ year < 58 kWh/sqm/year (Benchmark EPI= 58 kWh/sqm/year)

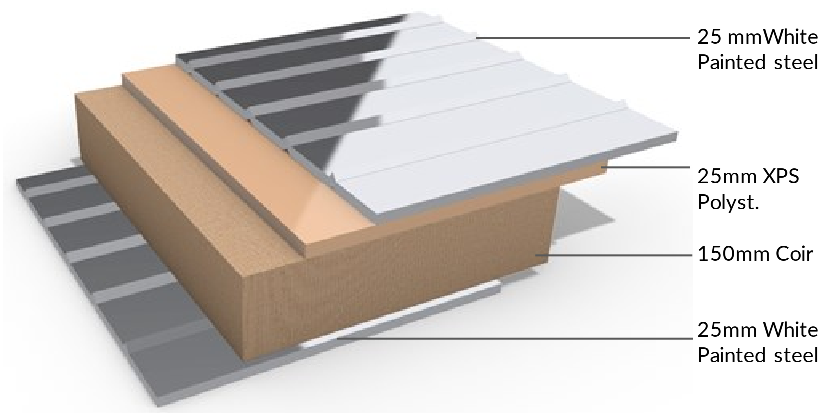


Figure 24: Roof Assembly

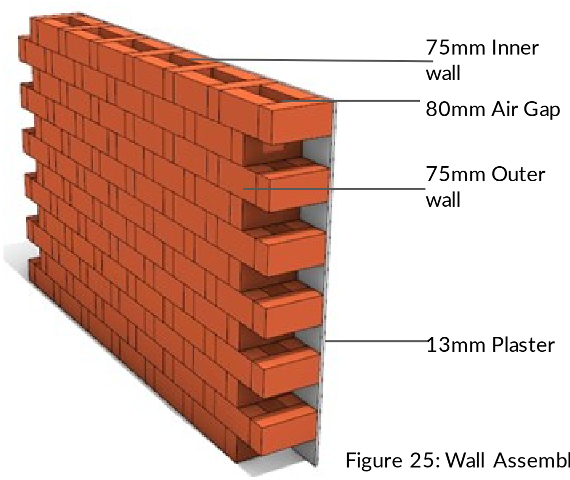


Figure 25: Wall Assembly

Water Performance

Water cycle and strategies

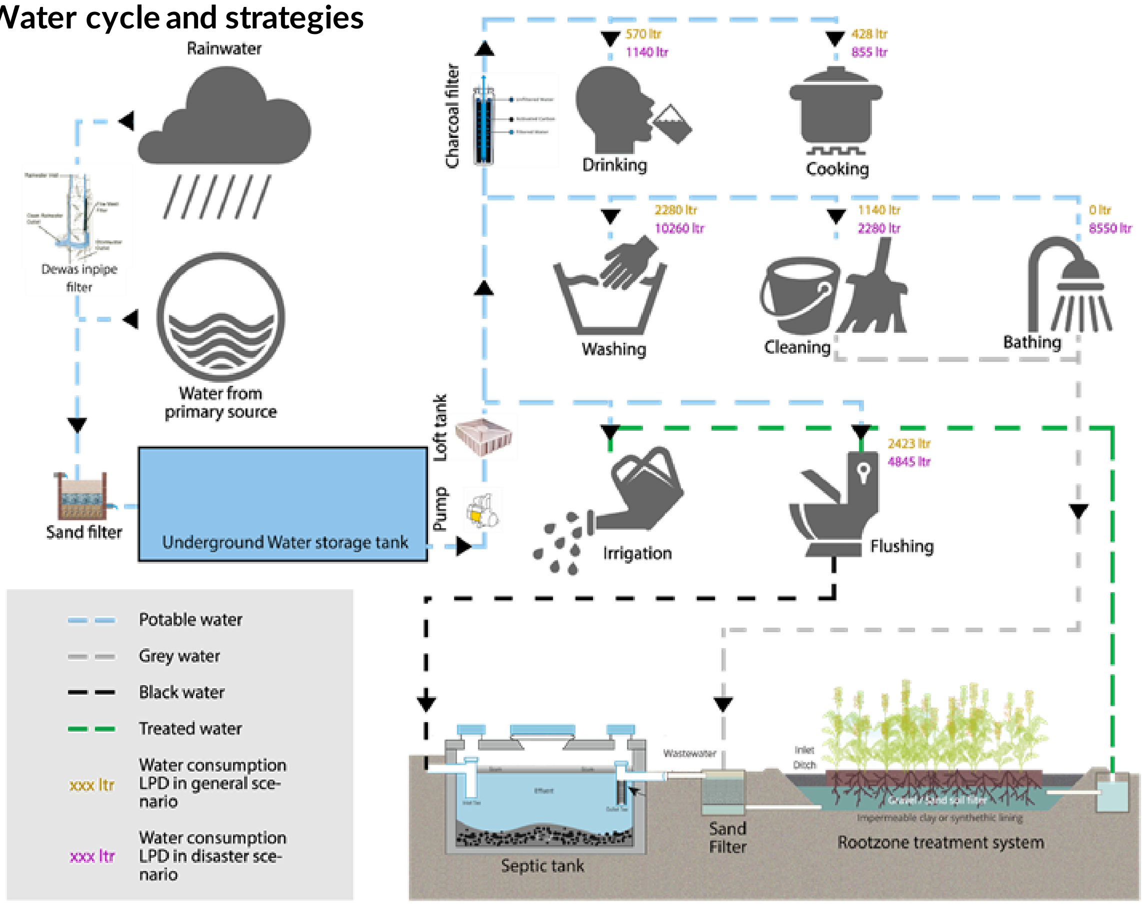


Figure 26- Conceptual water flow and solutions

The net zero water system implements a local closed water cycle without using the groundwater. The filtered potable water is used for drinking, cooking and washing whereas the non- potable water which is the grey water is treated in the root zone treatment system for bathing, flushing and irrigation purpose.

Root zone treatment :

- Aerobic rootzone water system is designed to treat greywater produced by maximum number of occupants which is 300 people.
- Reeds used are flax lily (*Dianella tasmanica*) and foxtail millet (*Setaria italica*).
- Reed beds of total area 450 sq. m. are provided considering an area of 1.5sq.m. per person.

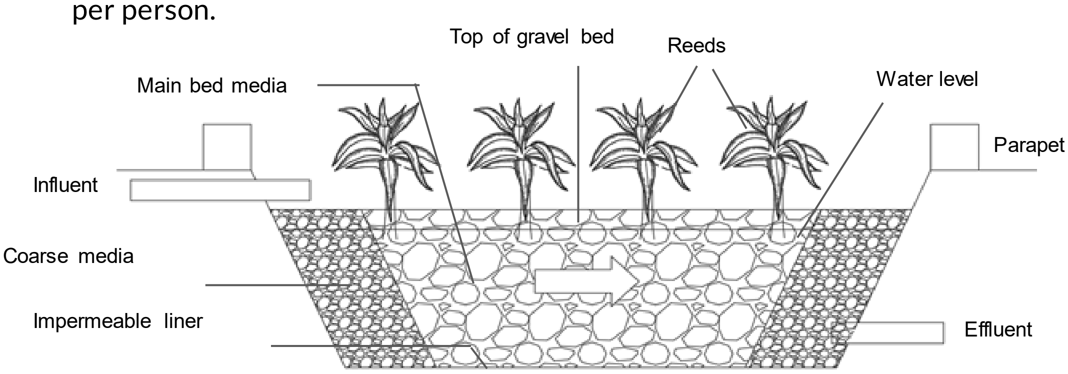
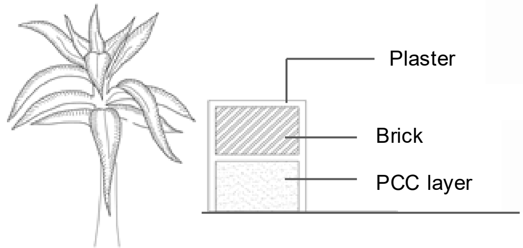
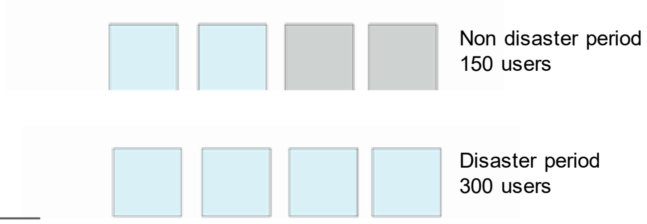


Figure 27 - Section of reed bed

Rainwater harvesting system

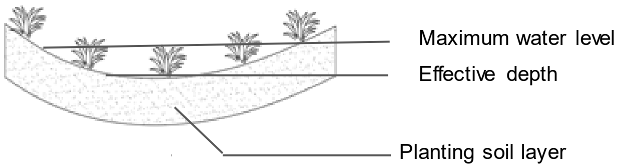


The edges of the reed bed are raised by a certain height to protect them from overflowing.



4 reed beds are used in a loop according to the no. of users during different periods. The blue coloured bed represents the active reed bed.

- A critical storage tank acts as a reserve tank for future use.
- Efficient water fixtures in the indoor helps to reduce the water usage on daily basis.
- The surface water collection is done through rooftop via gutter channeling and swales through open channeling.
- The water calculations and cycle are
  a) Disaster scenario (300 occupants)
  b)General scenario (150 occupants)



Water channel detail

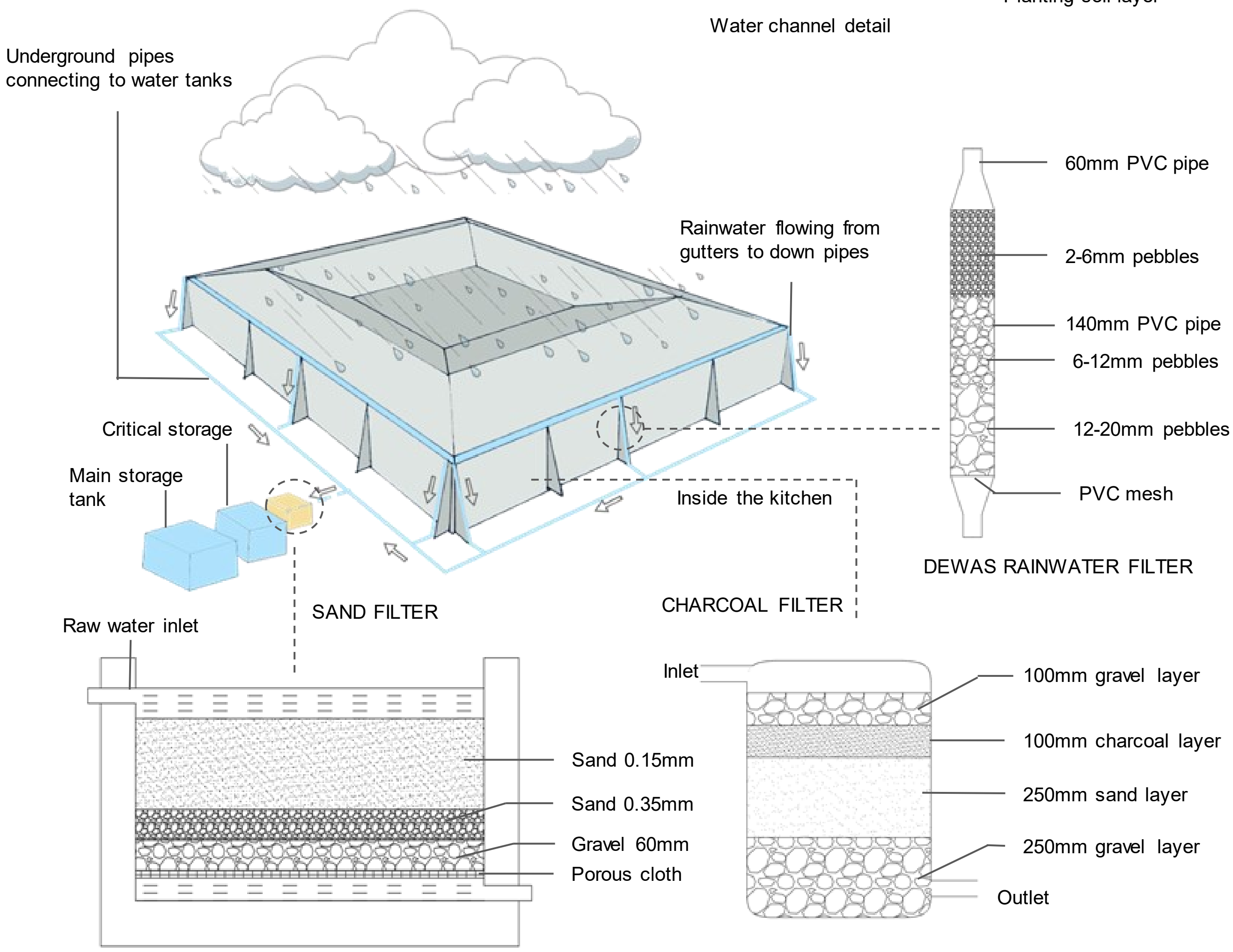


Figure 28 - Rainwater harvesting system details

Net-zero water cycle design

DOMESTIC USE	
Use lpd/hd	95
No.of ppl	300
Total lpd	28500

IRRIGATION USE	
L/m2	1
Area m2	2500
Total lpd	2500

END USE	PERCENT USE	USE IN LPD	GREY WATER IN LPD	BLACK WATER IN LPD
Bathing	30	8550	8550	
Washing	20	5700	5700	
Cleaning the place	8	2280	2280	
Washing utensils	16	4560	4560	
Drinking- Humans	4	1140		1140
Cooking	3	855		855
Toilet Flushing	17	4845		4845
Others	2	570	285	285
TOTAL		28500	21375	7125

		CONSUMPTION				WATER SOURCES				
Month	Days in month	Domestic Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Primary water source	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	883500	5%	3,875	887375		748879	662,625	220875	524129
Aug	31	883500	5%	3,875	887375.05		895642	662,625	220875	1195020
Sep	30	855000	50%	37,500	892,500		822906	641,250	213750	1766676
Oct	31	883500	30%	23,250	906,750		837539	662,625	220875	2360090
Nov	30	855000	90%	67,500	922,500		377882	641,250	213750	2456722
Dec	31	883500	90%	69,750	953,250		24102	662,625	220875	2190199
Jan	31	883500	90%	69,750	953,250	20,000	29697	662,625	220875	1949271
Feb	28	805125	90%	63,563	868,688	20,000	47773	603,844	201281.25	1752200
Mar	31	883500	90%	69,750	953,250	20,000	58533	662,625	220875	1540109
Apr	30	855000	90%	67,500	922,500	20,000	91673	641,250	213750	1370532
May	31	883500	90%	69,750	953,250	20,000	245322	662,625	220875	1345229
Jun	30	855000	90%	67,500	922,500	10,000	581887	641,250	213750	1655866
Total						110000	1,054,886	3874218.8		8,636,054

Table 4 - Water calculations during disaster scenario

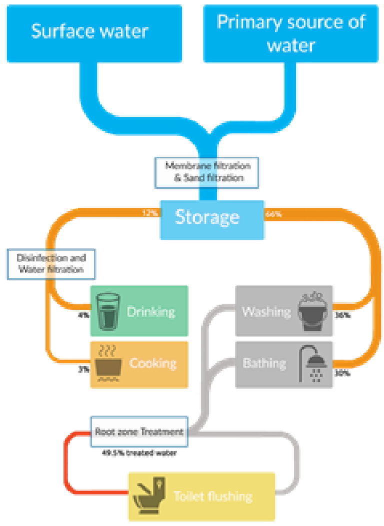


Figure 29 - Water cycle during disaster

DOMESTIC USE	
Use lpd/hd	95
No.of ppl	150
Total lpd	14250

IRRIGATION USE	
L/m2	1
Area m2	2500
Total lpd	2500

END USE	PERCENT USE	USE IN LPD	GREY WATER IN LPD	BLACK WATER IN LPD
Cleaning the place	8	1140	1140	
Washing utensils	16	2280	2280	
Drinking- Humans	30	4275		4275
Cooking	14	1995		1995
Toilet Flushing	30	4275		4275
Others	2	285	145	140
TOTAL		14250	3565	10685

		CONSUMPTION				WATER SOURCES				
Month	Days in month	Domestic Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Primary water source	Rainwater	Greywater (L)	Blackwater (L)	Total Stored
Jul	31	883500	5%	3,875	887375		748879	662,625	220875	524129
Aug	31	883500	5%	3,875	887375.05		895642	662,625	220875	1195020
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Jun	30	855000	90%	67,500	922,500	10,000	581887	641,250	213750	1655866
Total						110000	1,054,886	3874218.8		8,636,054

Table 5 - Water calculations during general scenario

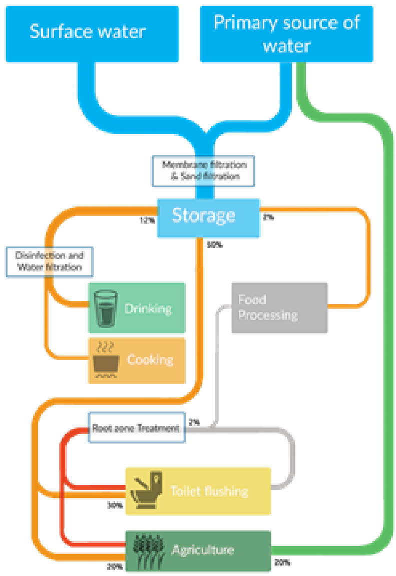


Figure 30 - Water cycle during normal conditions

Total capacity of rainwater storage tank =357.116m^3

Consider capacity of critical tank to be 20% of total capacity.

Hence, capacity of critical storage tank = 71.423m^3

For critical tank, consider h = 3m and l=b.

Hence, l=b= √ 71.423/3 = 6m

Therefore, the size of critical storage tank will be 6m x 6m x 3m.

Now, capacity of main tank = 357116 litres -714230 litres = 285690 litres = 285.69m^3

Here, we consider 2 tanks of same size.

So the capacity of each tank will be 285.69/2 = 142.8m^3

Now, considering h = 3m, and l=b,

we get l = b = √142.8/3= 6.8m

Therefore, the size of each tank is 6.8m x 6.8m x 3m.

Treated greywater tank calculations:

Grey water generated in 10 days = 35650 litres = 35.65m^3

Now, considering h = 3m, and l=b,

we get l = b = √35.65/3 = 3.4m

Therefore, the size of the tank is 3.4m x 3.4m x 3m.

Resilience

Reducing vulnerability, so that hazards do not become disasters!

According to the hazard map of India provided by the BMTPC, the site is prone to very high damage risk due to cyclones. The wind speed prevailing is 50 m/s. The Ganjam district was the most affected by cyclone Phailin. The cumulative amount of rainfall during this spell was as high as **241.1 mm** in the district and about **2,812 villages have been affected.**

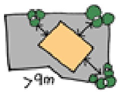
Cyclones bring with them high wind speeds, storm surge or tidal waves, rise in sea level and accompanied by heavy rainfall. However, since our site is located far from the coastal area the occurrence of flood is not observed.

Analysis of the prevailing risks associated with cyclone hazard prevailing at site

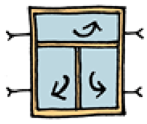
1. Uprooting of trees which disrupt transportation and relief supply missions.
2. Damage to improperly attached windows or window frames.
3. Damage to roof projections, chajjas and Sunshades.
4. Overturning failures of compound walls of various types.
5. Failure of weakly built walls and consequent failure of roofs and roof covering.
6. Failure of roofing elements and walls along the gable ends particularly due to high internal pressures.
7. Failure of large industrial buildings with light weight roof coverings and long/tall walls due to combination of internal and external pressures.
8. Brittle failure of asbestos - cement (AC) sheeting of the roofs of Industrial sheds.
9. Transmission lines, owing to their height, are highly vulnerable to cyclones.
10. Piped water supply systems and tube/bore wells were damaged.
11. The waste disposal sites should be located at a place which will not be washed away by storm water drainage over/excess flows.

Disaster risk reduction strategies adopted

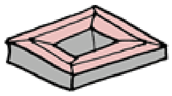
1. Trees are places 9m apart from structure to avoid any kind of damage to structure



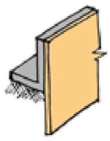
2. Window details allows for a flexible use where the strong wooden shutters of the windows act as Chajjas



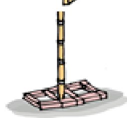
3. Compact building design to avoid various angles and roof projections



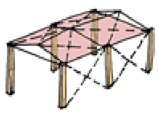
4. A metal sheet pile is attached to the retaining compound wall from outside to retain the earth



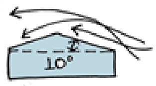
5. Additional bamboo reinforcement is added to rat trap bond walls



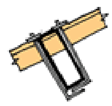
6. Cross Bracing is provided for space truss and wall for extra stability



7. Low pitched roof reduce heavy impact on roof as well as walls and buttresses are provided for additional support for columns

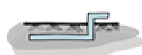


8. Fixing the roofing sheets to the purlins with J bolt with cement sheet at top for rigid joint



9. Emergency Restoration System (ERS) with 42 - 220 kV towers and two 400 kV towers by the Odisha Government

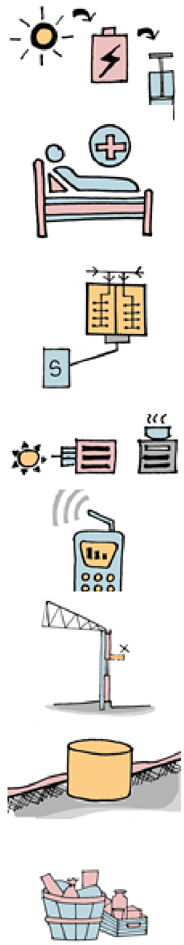
10. Underground piped water supply is provided to avoid damage



11. Waste disposal is located at south west side so that it will not get affected by storm water

12. Power supply at water pumping stations and installations should be provided with back up generator sets to run the systems in the absence of power due to cyclones.
13. Health and safety of the community is at risk due to the post disaster health issues.
14. Improper access to sanitation facilities and backflow of sewage.
15. Depletion and lack of access to cooking fuel needs.
16. Loss of communication and connect to outdoor for resources and emergency help.
17. Lightly connected or movable objects can be flung around or detached causing damage to other building elements.
18. Storm surge causes temporary flooding and backflow of sewage.
19. Food supply and emergency services get interrupted.

12. Batteries running on solar power helps in pumping water incase of power cut off
13. Medical centre is provided for post disaster diseases and other health issues
14. Sanitation facilities are easily accessible from common area and collection tanks are placed on the sloping side to avoid backflow of sewage and water.
15. Solar stove - Stores sun power to thermal storage with optimal heat retention
16. Satellite navigation phones are provided for communication
17. Design is built immovable and projection free
18. As sewage tank is provided itself at slope so terminate to the back flow
19. There will be sufficient food storage during disaster and services like medication and sanitation are easily accessible



For **medium- and long-term resilient building** the steps taken are:

- **Safety of livelihood:** The community neither has the minimum capacities to withstand the damage nor they have the economic support to recover from the losses incurred in the hazards and come to normalcy as far as the securities of the basic living needs are concerned. The cyclone shelter will function as socio-economic hubs at the village level by providing them a place to stay till the time they have the funds to recover and emerge stronger. The agro-processing unit, and the stored produce will continue to serve as a means of resource for food as and when required.
- **Safety of Income:** The agro-processing unit will continue to run in times of cyclone, giving the habitants a means to generate produce and earn. The bamboo prefabrication plant would bring in employment in near future (once the situation is under control) adding to the source of income generation. The plant will also cater to the needs of the shelters present in nearby villages and act as potential source of income for those villagers too.
- **Community connections for bringing in and sending out resources:** Ensure participation of the vulnerable community including the shelter village and served villages in disaster preparedness activities and in management and maintenance of the shelter and organize community-based capacity building activities like workshops, seminars, training programme on disaster related skills, padayatra etc to sensitize, involve and to strengthen the community.

Resilience strategy details

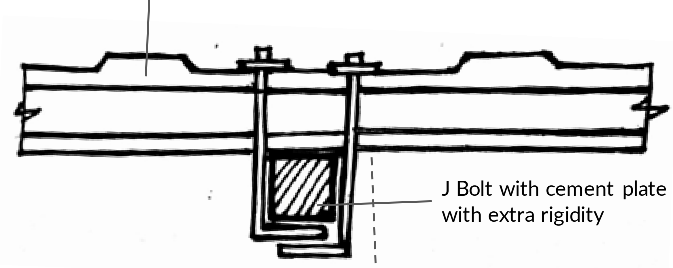


Figure 31 - Sheet roof joinery detail

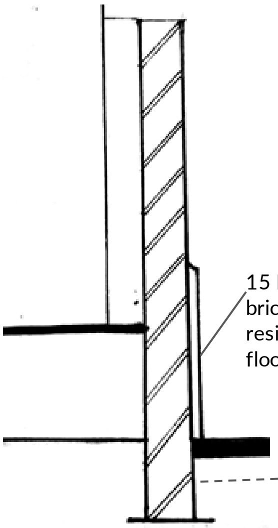


Figure 32 - Plastering detail

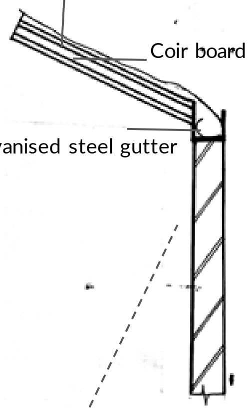
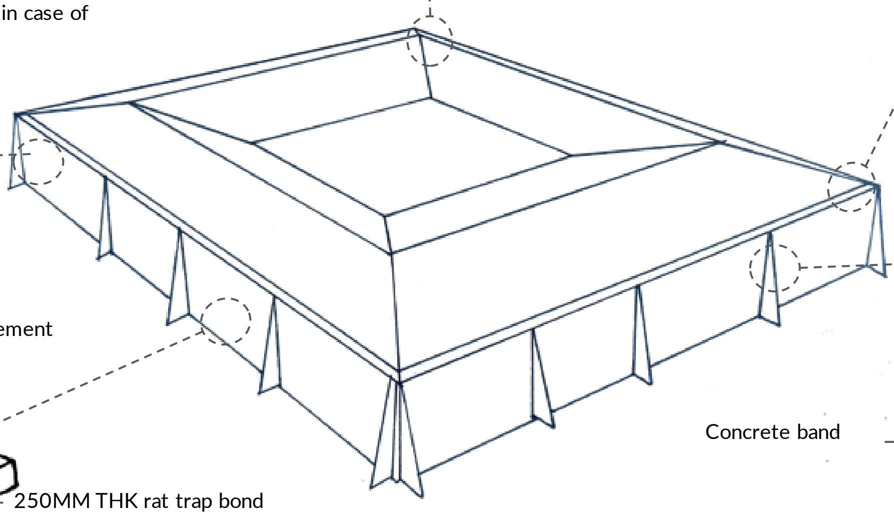


Figure 33 - Gutter detail



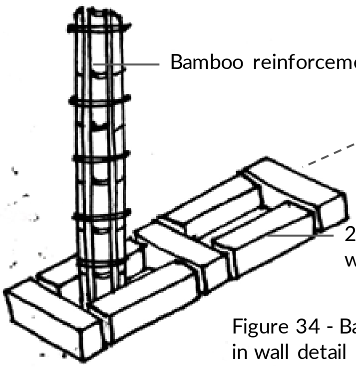


Figure 34 - Bamboo reinforcement in wall detail

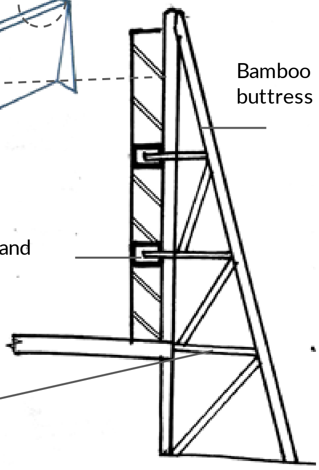
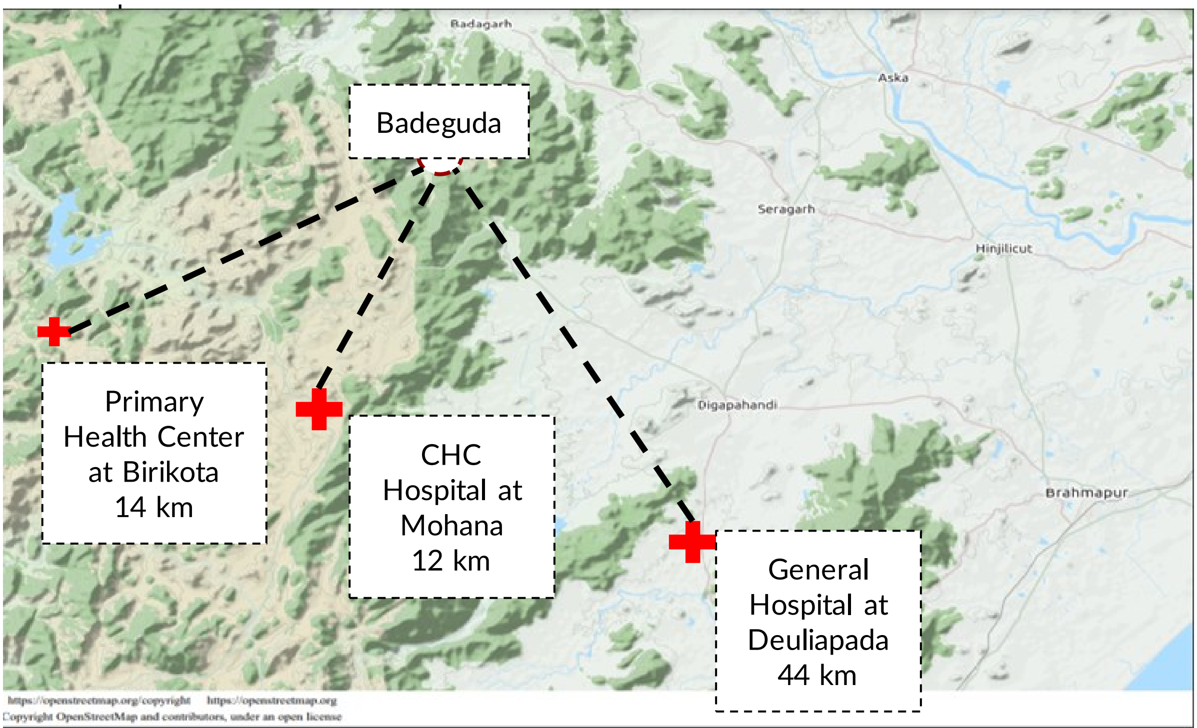


Figure 35 - Wall Buttress detail

Identification of institutions and infrastructure available in the vicinity for plan for

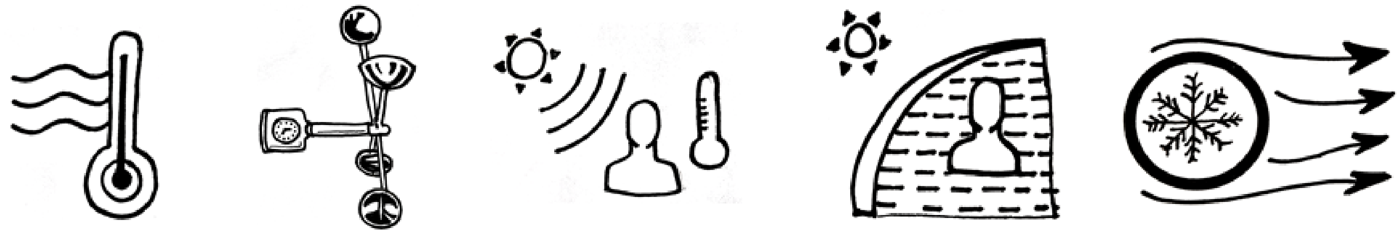


Resilience Metric

- **PASSIVE PERFORMANCE**

How many hrs in a year can a building provide comfort without using mechanical devices?

The cyclone shelter can work provide **6541.25 hrs** of thermal comfort with passive performance only, that is, without the use of any mechanical heating, cooling or ventilation device.



AIR TEMPERATURE **AIR SPEED** **RADIANT TEMPERATURE** **SHADING** **AIR MOVEMENT**

- **SUFFICIENCY AND AUTONOMY FOR CRITICAL FUNCTIONS**

Annual balance between import and export of energy and water resources, storage of energy and water to work during cut off of these supplies is maintained.

How many days of autonomy for critical functions can the building provide?

1. **Energy including lights and pumping of water supply and sanitation**: During disasters, **20, 200 Ah batteries** integrated with 30 solar panels (Storage capacity for **2 days each**) caters to the load requirements.
2. **Communications:** During disasters, **06**, Handheld Amateur Radio Walkie Talkie 2 Way Radio long range integrated with lithium batteries (**capacity for 5 days each**) caters to the requirements.
3. **First responder medical equipment:** During disasters, the medical room provided in the shelter can provide medicines for **15 days** and the medical equipment can run for **5 days** to cater to the requirements.
4. **Cooking fuel:** During disasters, **5-solar cookers** provided in the shelter can provide a means for cooking 3 meals a day for **15 days with 72 hours** of solar power storage capacity each, to cater to the requirements.
5. **Water facility:** The water consumption during cyclone is 28500 LPD and the storage capacity is 357113 Lts therefore the shelter can run for **12 days**.

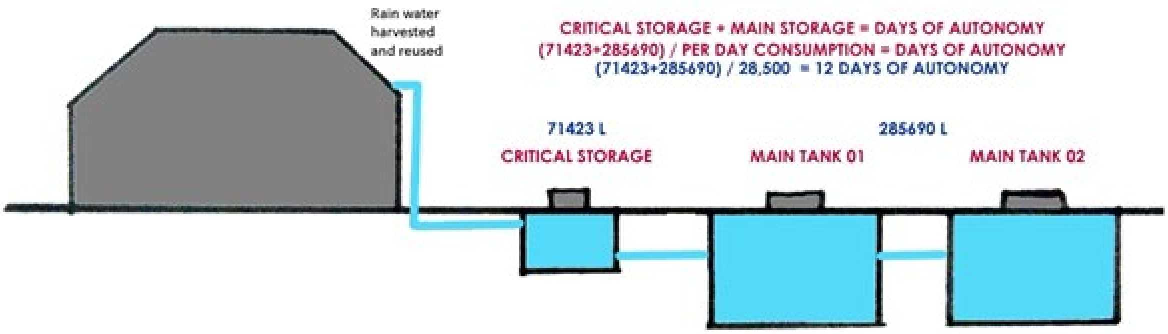
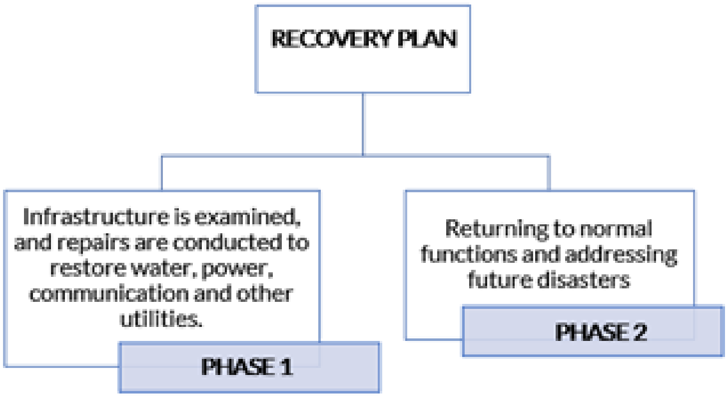


Figure 36 - Water storage autonomy calculation

A Recovery Plan to sustain critical operations after a disaster event or supply outage



Provide integrated mass care and emergency services. › Undertake required damage and needs assessments › Providing safe water supplies through labour intensive techniques using cash-for-work › Priority power supply restoration process by making repairs to electrical facilities, local distribution substations are checked first, Main distribution supply lines are checked next › Reducing obstacles and hazards posed by debris and solid waste and cleaning up of primary transportation routes › Clear farm land to enable communities to replant their farms through cash for work › Facilitate the access to markets and the rehabilitation of market premises.

Principles of Resilient Design in our Proposal

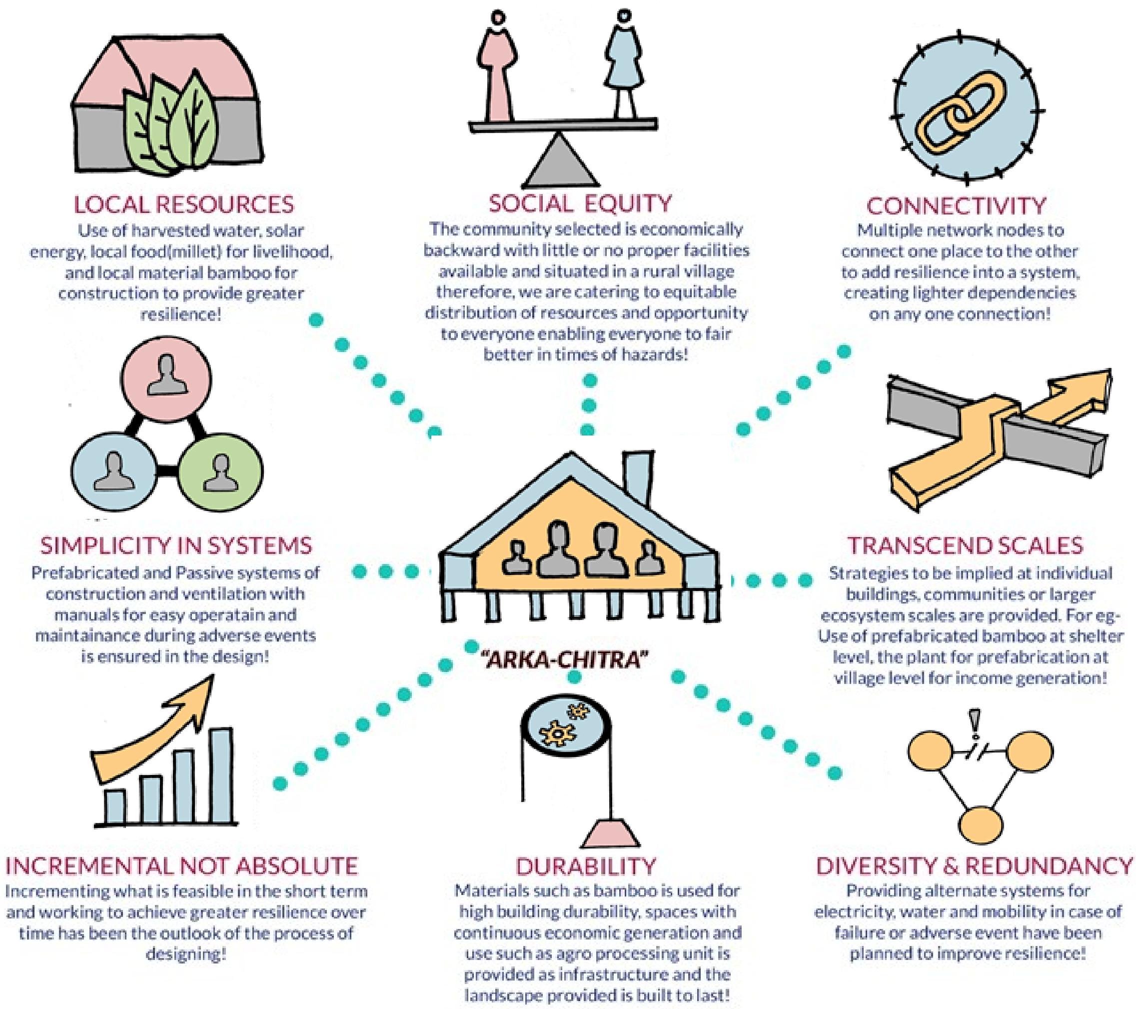
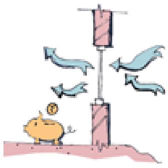


Figure 37 - Principles of resilient design

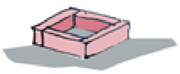
Affordability

Strategies and parameters considered for affordability



Effective ventilation strategies

Maximizing the use of natural ventilation to reduce mechanical and electrical load.

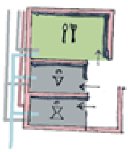


The correct choice of construction materials

Selection of Rat Trap bond masonry for reducing material consumption by 25 to 30 percent and provides better thermal insulation.

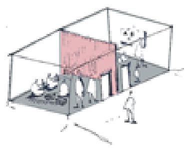
Use of locally available materials

Using local materials to reduce transportation costs and to ensure the engagement of people with it.



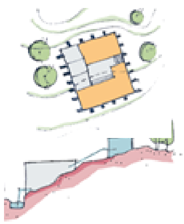
Planning strategies

Effective planning done with site considerations by clubbing service core areas such as toilets and kitchen to reduce the length of pipes for better efficiency in terms of energy and savings in terms of reduced pipeline and pumping cost.



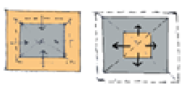
Multipurpose spaces

Creating multipurpose spaces/ multifunctional spaces for complete utilization of structure during cyclonic as well as non-cyclonic conditions



Minimizing excavation

Minimizing cut and fill with contours by giving two levels to the structure, placing spaces parallel to the contours. Soil cut is used for filling the lower portion and creating earth berms.

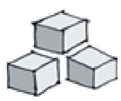


Minimizing circulation area

Reducing circulation by efficient planning of the built-up area.

Reducing construction period

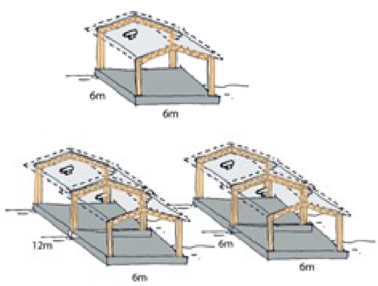
Creating prefabricated bamboo reinforced members' kit to save construction time of Space frame members.



Modularity

Creating a modular structure for faster and economical construction concerning different site conditions.

Cost per module



Cost of one 6mx6m module = 7.4 lakh

The modularity of the structure is achieved with the help of these 6mx6m modules. They can be replicated according to the design and site considerations of different regions.

Materials used for construction: Rcc Foundation + Bamboo Create columns + Brick wall + Bamboo buttress + Bamboo truss + Steel and Coir pith insulation.

Revenue Divisional Commissioner (RDC) has been considered to look into the executive administration of ten districts in Odisha, and Gajapati is one of them. Taking this into consideration, we have provided detailed cost estimate for the proposed design of cyclone resilient shelter based on the particular rates for building construction to be followed by the the districts coming under RDC zone.
Mechanization of construction, in terms of on-site quick assembly, replicable and modular design of building components have contributed to control on timeline and overall costs of the project.
Prefabricated bamboo trusses and buttresses are used to reduce rework and wastage and thus result in a better quality of construction. This also helps to reduce labor costs significantly as there are no special skills required. Semi-skilled adult labours can be employed who can work for 8 hours per day and a weekly day of rest. (CPWD, 2019) (Odisha, 2013)

Ganjapati distric considered under RDC zone of Odisha	
Reference baseline cost estimation	Disaster resilient shelter constructed at Lakhimpur, Assam
Reference for proposed design cost estimation	SOR For RDC zone Odisha state 2013
Construction peroiod	1-1.5 Years
skill level of labour	Semi-skilled
Payback period	22.77 years
Utility cost reduction	Rs 21493.26

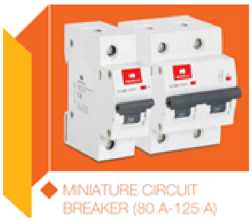
Table 6 - General information of cost

Products Specifications

'Selco' our project partner has provided us a wide range of products mainly for the agro-processing unit which will help to improve the quality of life in Ganjam. Along with that we have also used few other products, a list of which is given below:

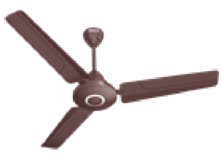
SVS Turbo ventilators

Millet mill



Euro-II circuit breaker

Rice huller



Havells Eficiencia neo ceiling fan

Vector De-stoner

CF De-huller

Product's name	Product's company/ brand and cost
ELECTRICAL AND ALLIED SERVICES	
Panels / Distribution board / Switch gears	Havells
Light fittings LED bulbs	Wipro
Light fittings LED tubelights	Wipro
Ceiling fans	Havells
Extract fans	Havells
PLUMBING AND SANITATION	
Fittings - Indian WC pan	Mark ceramic
Fittings - European WC	Cera EWC's Callaghan
Fixtures - Flush tank	Cera EWC's Callaghan
Fixtures -Faucets	ECO 365
Sand filter	Dewas filter
Charcoal filter	
EQUIPMENTS AND FURNISHING	
MEDICAL ROOM	
Refridgerator	Samsung
Nebuliser	Philips
ECG Machine	Bonet
Oxygen concentrator	Evox
Centrifuge	Selco
Microscope	Selco
Sterilizer	Airex
AGRO PROCESSING UNIT	
Millet grader	Selco
Millet de-stoner	Selco
Millet huller	Selco
Flour mill for ragi	Selco
Solar panels	Selco
The hurricane turbine ventilator	SVS wind driven turbo ventilator

Table 7 - Products/ Brands of equipment

Business Model

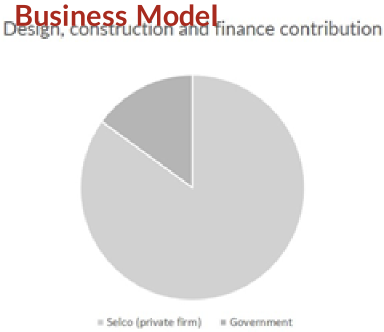


Figure 38 - Contribution according to DBFO

Figure 39 - Project handling stages

DBFO (design–build–finance–operate)

A DBFO structure differs from BOT in a way that during the concession period the 'Selco' owns and operates the facility with the prime goal to recover the costs of investment and maintenance while trying to achieve higher margin on project. There is no actual ownership transfer. The 'Selco' is responsible for the design and construction of a piece of infrastructure for the government of Odisha, which is the true owner. Moreover, the private entity has the responsibility to raise finance during the construction and the exploitation period.

Life cycle cost

Systems considered for life cycle cost analysis

Energy system	Distribution
1. Alternative energy systems (e.g., solar photovoltaics, solar thermal, fuel cells) a) Solar energy is the cheapest as compared to other energy sources According to site conditions like wind speed solar energy is advisable.	Operational cost = 80% Repair and maintenance =1 Utility cost = 5%
2. Air distribution systems (e.g. variable volume vs. constant volume, overhead vs. underfloor)	
a) Rejected: Earth air tunnel	Operational cost=50% Repair and maintenance =4 Utility cost=10%
b) Turbo ventilators - hurricane turbine ventilator	Operational cost=90% Repair and maintenance =5% Utility cost=5%
3. Indoor lighting sources and controls a) Rejected no courtyard and only windows	Operational cost= 80% Repair and maintenance= 1 Utility cost= 10%
b) Now Skylights, courtyard	Operational cost =90% Repair and maintenance =5 Utility cost= 5%
4. Building Envelope	
a) Rejected- mud wall	Operational cost =50% Repair and maintenance =4 Utility cost=5%
b) Now Rat trap bond	Operational cost= 85% Repair and maintenance =1 Utility cost=5%
5. Roofing systems (various materials and insulation methods) a) Rejected- GI sheet, coir with insulation	Operational cost= 70% Repair and maintenance =25 Utility cost=5%
b) Now Sandwich panel of White painted steel with coir and insulatior	Operational cost = 70% Repair and maintenance =2 Utility cost=5%
6. Glazing, delighting, and shading options	
a) Rejected- sliding window	Operational cost= 80% Repair and maintenance= 1 Utility cost =5%
b) Now Casement window	Operational cost= 80% Repair and maintenance =1 Utility cost= 5%
7. Siting/Massing a) Rejected- One level stilts structure	Operational cost =60% Repair and maintenance =3 Utility cost=5%
b) Now two levels to structure to minimize cut and fill	Operational cost=90% Repair and maintenance =5 Utility cost=5%
8. Orientation, floor-to-floor height, and overall building height	
a) Rejected- North south facing rectangular block	Operational cost= 55% Repair and maintenance =2 Utility cost=10%
b) Now 45 degree tilt to make it parallel to contour	Operational cost= 80% Repair and maintenance =1 Utility cost= 10%
9. Structural Systems a. Rejected- Bamboo columns only	Operational cost= 60% Repair and maintenance =25% Utility cost=15%
b. Now Bamboocrit structural members will help to reduce maintenar	Operational cost =85% Repair and maintenance =10% Utility cost=5%

Table 8 - Distribution done for life cycle cost (in percentage)

Design is developed considering the maximized use of passive strategies instead of active ones which will lower repair, maintenance and utility cost to achieve better life cycle cost.

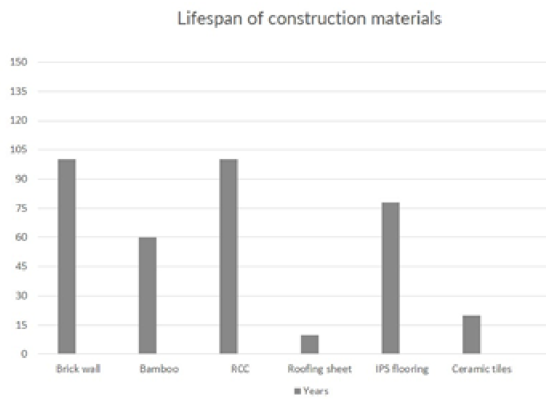


Figure 40 - Lifespan of construction materials

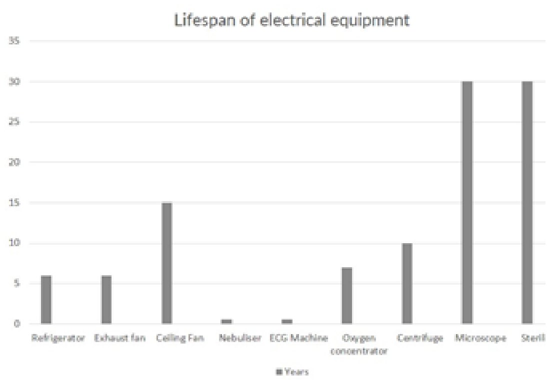


Figure 41 - Lifespan of electrical equipment

Innovation

Cyclone Resistant Window Protection

- This window is divided into three parts; Top hung window, Double shutter side hung window and internally placed casement window.
- Internally operated securing mechanism to protect the inner glass sliding window during cyclones.
- Designed in such a way that the top part can act as a sunshade when extended out and bottom part to reduce the heat gain from windows in period of excessive heat.
- The locking arrangement of shutters is sturdy and the window frame is fixed in walls using holdfasts

All open in regular scenario

Figure 42 - Cyclone resistant window

Only ventilator open

Only lower shutters open

All closed during cyclone

Figure 43 - Modes of Operation

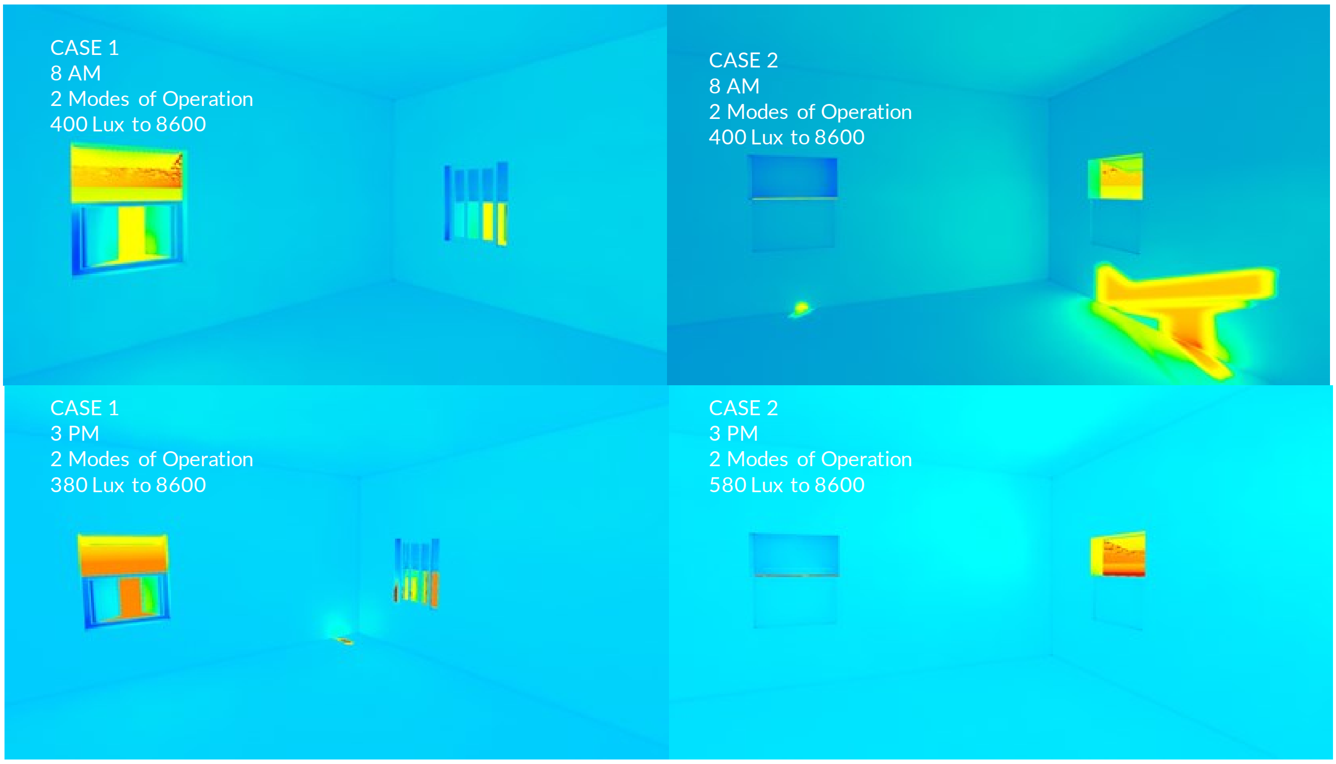


Figure 44 - Modes of Operation and Daylight- Glare Reduction

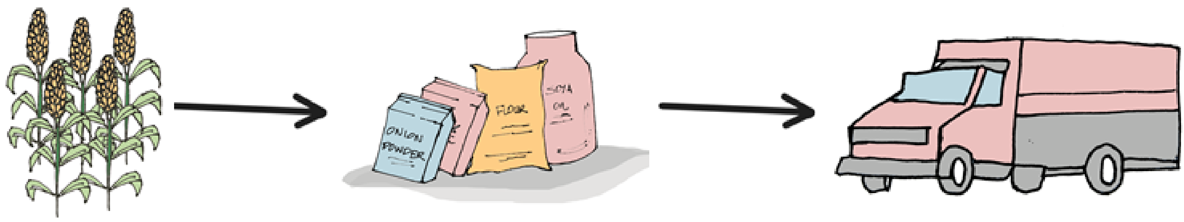
Scalability and Market Potential

Strategies for replication or large-scale implementation

Sustainable Use-

- The more a shelter is used in normal time, the better it is maintained, the more successfully it serves in emergencies. Regular use also provides economic justification for the investment in the form of small user fee.
- Nearly 85% of Orissa's population (3,12,10,602) live in the rural areas and depend mostly on agriculture for their livelihood and a **Centre for Agricultural Development** suited as the best alternative use to the cyclone shelter.
- Such centers can engage in all or some of the following activities that will help uplift and support the economic status of the disaster prone are during non disaster times-

1. **Agro processing** will help in diversifying income by selling of processed products.
2. Will create more employment opportunities in the Center itself.
3. Bring financial wisdom from constant counselling from **Self Help Groups**.
4. The Center will help the farmers explore appropriate **Farming Technologies** to yield best results from their produce.

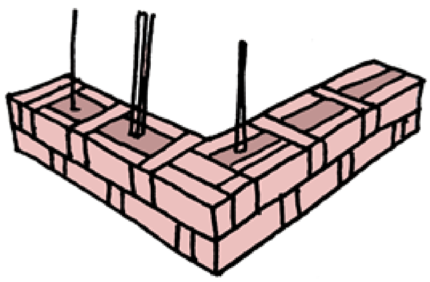


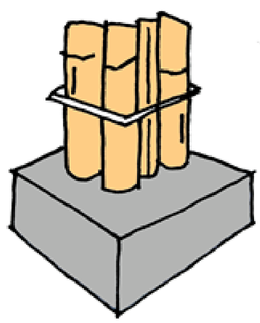
Constructability

For a project to be replicable in terms of constructability, the following four factors need to be addressed-

1.Ease of Manufacturing

Ease of manufacturing or constructing comes with immediate availability of construction materials and use of local workforce



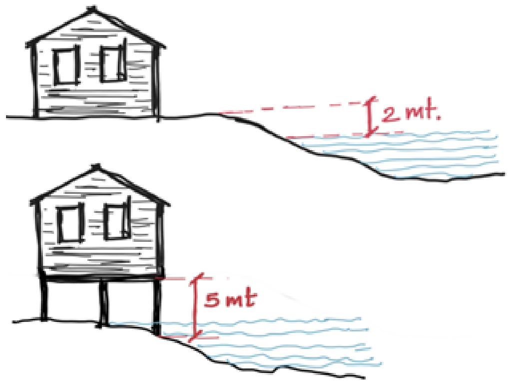


- The design proposes prefabricated bamboo columns and bamboo space frames. As Bamboo is a locally available material in Odisha.
- Nevertheless the material could also be replaced by wood , or steel depending on the location and availability
- Prefabrication would help in reducing the construction time and also maintain the quality.

- Proposed design uses brick walls in rattrap bond with reinforcement, As bricks are a staple material in the project area.
- However, it can be replaced with locally available material like stone, compressed earth blocks, etc

2. Ease of Customising

Ease of customization refers to the liberty to make few changes in the given set of guidelines based of factors like climatic conditions, site terrain. material availabilitv etc. These are some guidelines identified are-

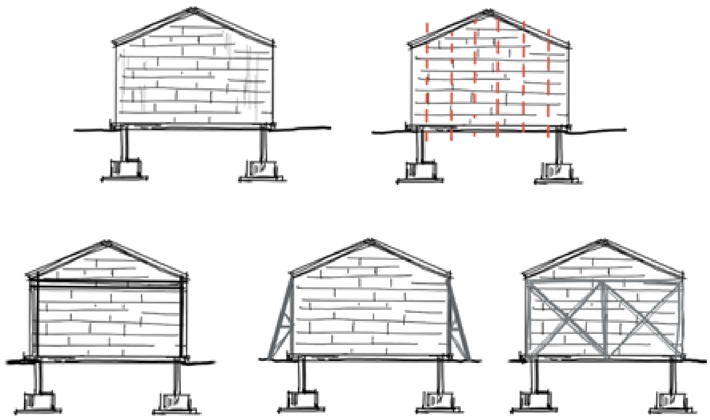


Site Location and Terrain-

- The project site should be at least 2 m above the high tide level and a flat terrain

- If the site is not on the required elevation, the structure should be elevated with stilts of not more than 5 meters.

Construction system -



- RCC foundation with load bearing walls for low intensity winds and flat terrain

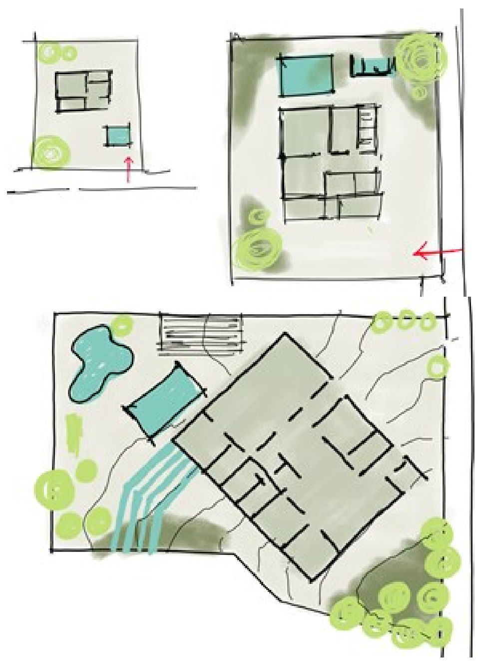
- RCC foundation with reinforced load bearing walls for greater intensity winds

- RCC foundation with RCC structure and infill walls with any locally available building materials where the for Multiple levels, (not recommended more than G+2)

- The roof will have no overhangs to keep smooth wind flow dynamics

- Additional support can be provided with piers, bracing, buttresses depending on the climatic conditions of the site

Scale of Site and Economic Feasibility



- Full fill basic necessities of kitchen and food storage, large covered space for habitation and water requirement.

- Additional habitable rooms, water treatment to help with the water requirement, earth mounding for directing winds.

- Additional habitable space, space for cattle and livestock. Water treatment in the form of reeds, water channelling with bio swales, additional water storage with artificial ponding, earth mounding and air tunnels for directing winds.

3. Ease of Maintenance

The physical maintenance of the structure will be taken care with its constant use in the non disaster times this is where the factor of Market Potential steps in.

But for a structure to be ready and functional during disaster times financial maintenance and feasibility is also important during non disaster times as well.

One should not just ensure that it is it financially self sustainable but in cases of poor rural areas such infrastructure should also serve as an asset to the village and its people.

In the given design proposal the following strategies have been used-

Bamboo Prefabrication unit

- A Bamboo Prefabrication unit is is conceptualized which would serve other neighbouring villages parts like prefabricated bamboo columns, trusses, space frames furniture, which will be used for construction in neighbouring villages.
- Bamboo is a sustainable material and using it instead of RCC cuts down the construction time.
- Bamboo being a local material is readily available and this will cut down on the transport cost and intern reduce the project cost.
- It will set a permanent local demand-supply chain which is extremely beneficial for development of a remote rural area.

Center for Agricultural Development

- The Center will help in the overall development of the occupation and village as mentioned in the '**Sustainable Use**' criteria.
- It can also be collaborated with various government schemes like-
- The millet processing can be collaborated with **Millet Mission by Government of Odisha** which promotes more use and consumption of millets to maintain a balanced diet and good health amongst people.
- It provides **remunerative price to the millet growing farmers**.
- The center could also collaborate with **SAMRUDHI under the Agricultural Policy of 2020**. It is designed to Promote technology in farming, adapt to climate change, expand markets, efficient use if resources, diversification of products, strengthening Institutions, etc.
- The Self Help Groups can collaborate with the **Odisha Livelihood Mission** which works towards prioritizing Livelihood concerns, economic empowerment for rural women. (Government, 2011) (IIT Kharagpur, September 2006) (India, 2006) (OSDMA, 2009) (Odisha, 2019) (Sheltercluster, September 2018)

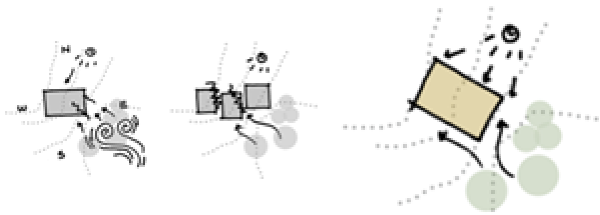
End Users

The residents of of Badeguda who are tribal inhabitants in the constant overcast of a disaster risk who could be primary workers, single women families, disabled persons, the children in the age group of 0-6 years and the aged are some of the most vulnerable population to be affected by cyclones.

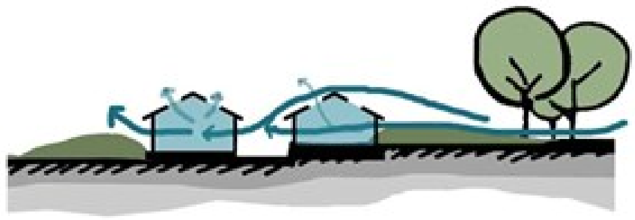
Anyone who neither has the minimum capacities to withstand the damage nor they have the economic support to recover from the losses incurred in the hazards and come to normalcy are considered as the end users for the cyclone resilient shelter.

Comfort and Environmental Quality

Passive and active strategies employed to achieve thermal comfort:

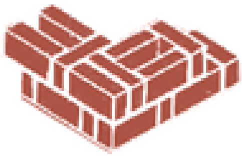


The building orientation tilted at 45^0 reduces the stress caused by cyclone winds by diverting them.



Opposite windows, roof ventilators and a central courtyard for effective cross ventilation.

Roof and Wall assembly



Rat Trap Bond- walls The cavity and increased thermal mass provides heat insulation.

Roof Assembly is such that the panels together form a higher thermal mass. Bamboo mats, Coir Boards, GI sheets are locally sourced materials.

Site Strategies:

1. Covering the ground with groundcover to reduce heat gain, lower the surrounding temperature.

2.Trees to be planted 9 m away from the structure to avoid damage during cyclone. Trees on S-SW side will reduce harsh sunlight, glare in the evening, will allow wind to pass through.

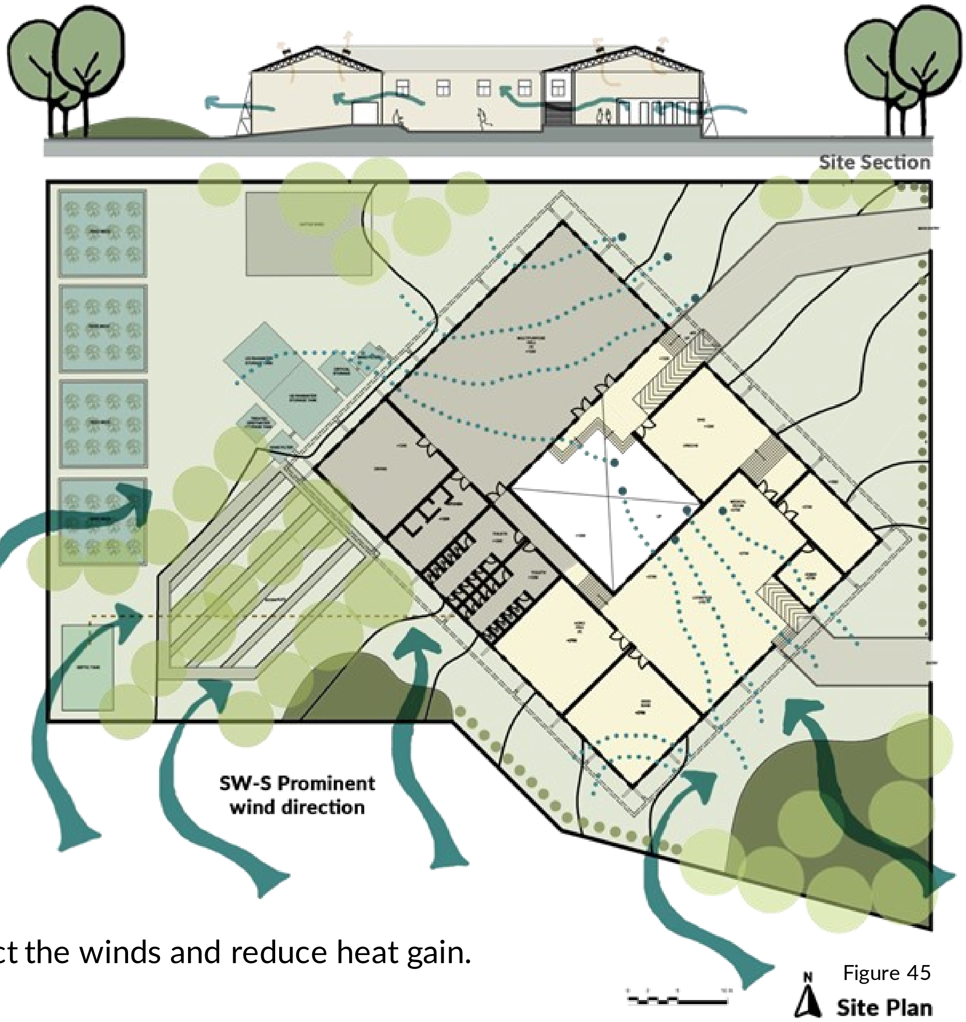


Figure 45

3.Earth Berms- To deflect the winds and reduce heat gain.

Cross Ventilation

Windows on the opposite side of the walls with required area are provided in accordance with wall-window ratio of 15-20% to achieve required ACpH* according to the function of the space and efficient air flow rate.

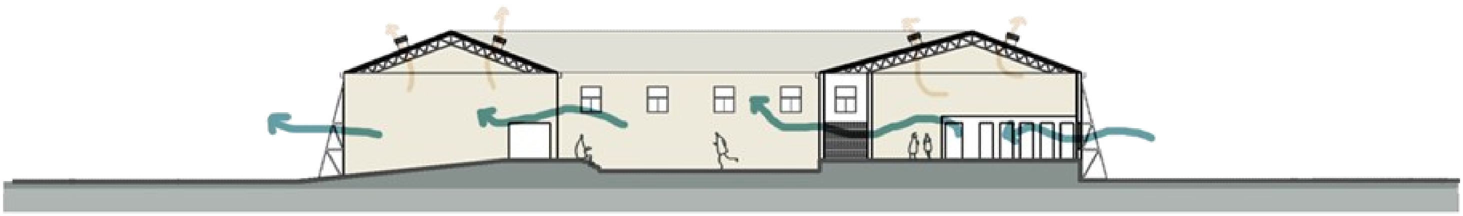


Figure 46 - Section (Cross Ventilation)

No	Activity Space	ACpH Required	Area SQ. M	Minimum area of openings required to achieve required ACpH in SQ.M
1	Multipurpose Hall	12	540	24.24
2	Logistics	12	340	13.07
3	Medical Room	6	72	1.31
4	Admin	4	36	0.44
5	Self Help Group (SHG)	12	144	4.36
6	Agro-Processing Unit	10	144	2.18
7	Seed Bank	10	144	2.18
8	Dining + Kitchen	15	216	9.70

No	Activity Space	Wall area SQ. M	Min Window area Reqd. SQ. M	Window area Provided SQ. M	Window Area to Wall Area Ratio
1	Multipurpose Hall	303.6	24.24	**70.2**	**16 %**
2	Logistics	148.8	13.07	**28.8**	**19 %**
3	Medical Room	55.8	1.31	**10.6**	**18 %**
4	Admin	18.6	0.44	**7.2**	**3 %**
5	Self Help Group (SHG)	74.4	4.36	**14.4**	**19 %**
6	Agro-Processing Unit	74.4	2.18	**14.4**	**19 %**
7	Seed Bank	74.4	2.18	**14.4**	**19 %**
8	Dining + Kitchen	138	9.70	**10**	**9 %**

Table 9 - *ACpH (Air Changes Per Hour) values referred from NBC, ASHRAE and SP 41 Handbook consisting of different public areas.

Ventilator sizes, no of vents:

Number of ventilators = Volume x ACpH / CFM of Ventilator
60

For Multipurpose Hall:
[18 x 30 x 4.6 x 12 (acph)] / 60 = 8 Ventilators
1972

No	Activity Space	ACpH Required	Air Volume CU. M	No of Roof ventilators required of 1972 CFM
1	Multipurpose Hall	12	2760	8
2	Logistics	12	2208	8
3	Self Help Group (SHG)	12	1104	4
4	Agro-Processing Unit	10	1104	4
5	Seed Bank	10	1104	4
6	Dining + Kitchen	15	1656	4

Table 10 - *ACpH (Air Changes Per Hour) values referred from NBC, ASHRAE and SP 41 Handbook consisting of different public areas.

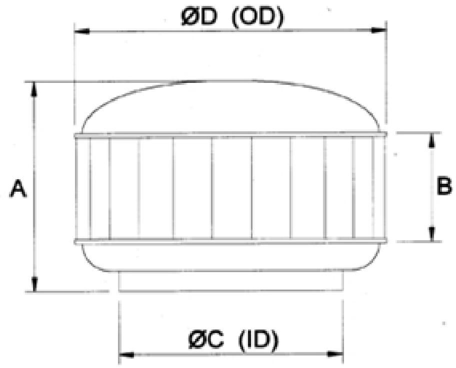
TECHNICAL SPECIFICATIONS FOR HURRICANE 900

Tolerance : Size +/-2mm
Weight +/- 0.1kg

Material :
Turbine & throat : Aluminium 5005 H34
Shaft: Aluminium 2011 T3 Dome & Skirt Aluminium 1200HD
Brackets : Aluminium 6060 T591
Spider (H600-H900 only) : Zinc passivate plated mild steel
Shaft (H900 only): Stainless Steel

Rotation Bearings :
Main bearing: Double row ball bearing - BWF30 -119Z
Spider bearing (H600-H900 only): Single row ball bearing - UB204-12S

Wind Speed Rating :
205.2km/h(57m/s) - Performance level 1
(As per AS 4740:2000 Natural ventilators - Classification and performance)



MODEL	A (mm)	B (mm)	ØC (mm)	ØD (mm)	Throat Area (m_2)	Weight (Kg.)
H900	643	400	897	1096	0.6319	18.1

Pitch to Project Partner

Statement of Necessity

a) Socio-economic factors contributing to vulnerability

People below poverty line, the primary workers, single women families, disabled persons, the children in the age group of 0-6 years and the aged are some of the most vulnerable population to be affected by cyclones.

b) End user and capacity of economic recovery

They have neither the minimum capacities to withstand the damage nor they have the economic support to recover from the losses incurred in the hazards and come to normalcy as far as the securities of the basic living needs are concerned.

c) Institutional and grassroots infrastructure

The other economic and institutional vulnerability remains with the grass root level institutional infrastructure done at the community and panchayat level that constitute the backbone of the rural economy and community support system.

d) Connectivity and resources

Very often the village road networks get affected which deprive the communities isolated from the supply and linkage network. The limited community and panchayat level resources can hardly be sufficient for restoration and the problem continues as a vicious cycle.

Impacts

1. Saving Lives

300 lives can be safeguarded with the disaster shelter with a expanded capacity of 600 people for people of surrounding villages. Evaluating the cost of saving even one life is monetarily impossible. Each life is precious!

2. Alternative use and its potential as a Community Asset

The programmatic diversity will ensure the continuous use of disaster shelter during regular scenario and create a socio economic hub for community interactions.

3. Enhancement of Livelihood

The annual average income of residents of Badeguda will increase by 7% by the introduction of Agricultural Resource Centre. (Based on annual average income of farmers according to Economic Survey of Odisha 2019 and District Statistical Handbook, Gajapati, 2018)

4. Nodal Center for Healthcare

Medical care currently is available at a Primary Health Center that is 15 km away and a Hospital that is 10 km away. The Cyclone Shelter being equipped with a medical room with basic medical equipment will act as a node for post disaster disease treatment, immunization and health improvement movements and can be expanded in phases.

5. Millet Revival and Nutritional Diversity

The nutritious millets traditionally occupied substantial part of the diets and crop systems in tribal areas of Odisha. Millets require less water and are more resilient to climate vulnerability. A special programme for promotion of millet has been undertaken by the Odisha Government to revive millets for household consumption. (Based on Economic Survey of Odisha 2019 under Mission Millet)

6. Women Empowerment through a dedicated Self Help Group

The Self Help Group space has been dedicated for socioeconomic activities and a creche provided makes working and training easier. The Odisha Government has also launched Mission Shakti with the objective of empowering women through gainful activities by providing credit and market linkage. (Based on Economic Survey of Odisha 2019 under Mission Shakti)

Wider Impacts
Our proposal aims beyond creating a self sustainable infrastructure by attempting to use the infrastructure as an asset to benefit the village community. The design solution will provide financial independence and security to the community.

Ease of Manufacturing
Local prefabricated assembly and module based plan

Ease of Customizing
Provision of adapting a standard design solution with a manual and guidelines

Ease of Maintenance
Local capacity building and income generation from alternative uses for funding maintenance and continuous use

Ease of Affordability
Local building materials and techniques reduce embodied energy and costs of transport

Impacts

Saving Lives	Alternative Use	Supporting Livelihoods	**Healthcare**	Capacity Building
1	2	3	4	5
Shelter	Community Space	**Agricultural Resource Center**	**Medical Center**	**Local Material Resource Hub**
To ensure physical safety of people who have no access to safe shelters	To provide a socio economic hub with programmatic diversity and ensure maintenance	Enhancing livelihoods with Millet Processing and seed bank to store climate resilient seeds	Medical center will act as node for treatment before, during and after disasters	Creation of local supply and demand chain for local prefabricated bamboo structures

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