Solar Decathlon India

# COMMUNITY RESILIENCE SHELTER

## FINAL DESIGN REPORT

April 2023

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## 1.A. LIST OF TABLES

## 1.B. LIST OF FIGURES

# 2. REVIEWERS COMMENTS

**REVIEWER 1**

| SECTION | REVIEWER'S COMMENTS | RESPONSE |
|---|---|---|
| Energy performace | Very good strategies with a good mix of passive design strategies and energy efficient fixtures for achieving low EPI. Detailed calculations and analysis provided in the annex. Good job! | Thank you |
| Water performance | Thorough and detailed presentation of strategies, calculations and analysis used for water management. Please recheck the calculations used for lpd water consumption especially for WC and Urinal. Not clear how you are able to achieve such less water consumption. Commendable job on achieving net positive annual water performance for the design. | Noted, has been incorporated in Section - 8.3, Water performance |
| Embodied carbon | Excellent analysis showing tradeoffs of the strategies chosen and good achievement in the reduction of embodied carbon. In the computation table in the appendix (section 9.4) need a description for what entails transport 1 and transport 2. | Noted, transportationn details have been mentioned in appendix section - 9.9 |
| Resilience | Good integration of resilience measures into the design of the building. Flash floods and soil erosion appear to be frequent hazards in Ittanagar and the design could consider building resilience in infrastructure for these hazards as well | Noted, has been incorporated in Section - 8.F, resilience |
| Engineering and operations | This section could touch upon the engineering system envisioned for the water system and waste management system. You could also touch upon energy generation from gym and prayer wheels and how the system around it works. Finally you could also touch upon a the labour situation, skills and any training needs for the construction and scalability of your ideas. | Noted, has been detailed in Section - 8.E, engineering and operations |
| Architectural design | Neat functional spaces and well thought out design and adjacencies. Would be nice to see some internal views as well in terms of material treatment. Finally do consider how an ambulance can access the field hospital. | Noted, Internal views are shown in appendix section-9.3 and the ambulance access is shown in architectural drawings |
| Affordability | Detailed and extension calculation to arrive at cot per SQM. Also consider labour cost involved especially in new methods of construction and training needs if required. | Noted, has been incorporated while doing the calculations |
| Innovation | Several innovations have been included that make this proposal very good. | Thank you |
| Health and well being | The design address both thermal comfort and ventilation requirements in an effective manner. | Noted |
| Value proposition | The value proposition is very good. It would be good to highlight the value for the project partners first in terms of the USP of the building design and then top it up with added value proposition such as apps and social media. | Noted, has been incorporated in section 8.J - value proposition |

**REVIEWER 2**

| SECTION | REVIEWER'S COMMENTS | RESPONSE |
|---|---|---|
| Energy performace | the epi looks good and is well presented | Thank you |
| Water performance | the performance report looks good, is detailed and well presented | Thank you |
| Embodied carbon | well collated data and good graphics | Thank you |
| Resilience | looks good. you can put earthquakes under resilience against disasters. Also, see if you can elaborate more on climate change and social resilience | Noted, has been incorporated in Section - 8.F, resilience |
| Engineering and operations | the drawings are very informative. please include hvac, electrical and waste and water management layouts | The project is naturally ventilated and hence does not use HVAC. Electrical, waste and water management layouts have been shown in the appendix section-9.4 |
| Architectural design | well presented and integrated architectural design | Thank you |
| Affordability | the affordability report and comparative analysis looks good | Thank you |
| Innovation | the ideas explored are creative and promising | Thank you |
| Health and well being | the points covered are relevant and the graphics are well presented and informative | Thank you |
| Value proposition | The points covered look good. You can open with a note covering the points for the project partner benefits and then move on to the application description | Noted, has been incorporated in section 8.J - value proposition |

# 3. EXECUTIVE SUMMARY

Fig. 1 Context


Fig. 2 Issues

**Earthquakes**
Seismic zone-v region
Richter scale magnitude - 2 to 6
Mercalli scale values - v to vii

**Floods**
Flash floods – due to heavy rainfall in downstream areas. Riverine floods occur majorly from the Dikrong River.

**Border tension**
Border disputes between India and China

**Landslides**
Debris flows - triggered by heavy rainfall.
Rockfalls - triggered by earthquakes
Soil slips - occuring on gentle slopes

**Project partner**
To address these issues, the Public Works Department, AP has proposed the construction of the State Disaster Management Agency office building in its capital, Itanagar, where SDMA experts can monitor the situation, and coordinate and facilitate relief efforts during crisis.

We, team EnCircle as part of the Solar Decathlon (India), have taken this opportunity to design a net-zero energy community resilience shelter for the PWD AP in Itanagar. We aim at improving the microclimate of the space (using GRIHA strategies) and provide shelter, aid, comfort, social resilience, water and food resilience to people during disaster. Our proposed project Aikyam, is a G+2 storeyed office building situated in the Civil Secretariat complex at Itanagar, with a site area of 3640 smt, adjacent to NH415.

**Office**
Uninterrupted workflow even during disaster

**Refuge shelter**
The design we finally arrived at, provides not only a comprehensive usage pattern during normalcy, but also can swiftly transform to a Community Resilience Shelter

The Second floor is reserved exclusively for the offices of the SDMA which has.

The First floor comprises of Workshops and a small conference room, along with day-care center for employee children, as also a dormitory for visiting officers from other locations. These, while meant primarily for the SDMA training purposes, can be pressed into service as a part of the disaster shelter, whenever necessary.

The Ground floor, mostly comprises of common-Use areas such as the Canteen facility, the appurtenant Kitchen and Store, but also Public-use areas such as a Bank, a Gymnasium, and Workshop / Auditorium which may be leased out if needed.

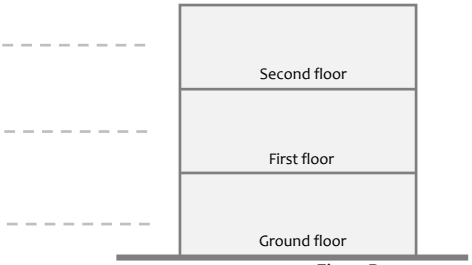


Fig. 3 Program

Design process and solutions – Being a structure that could function as community refuge, our main aim was to provide resilience during all circumstances. The potential disasters on site are landslides and earthquake. Floods are not an issue due to the slope of the site. Landslides are countered using gabion walls while earthquakes are countered using pile foundation, bamboo reinforced walls and other material usage like polycarbonate and linoleum.

## HIGHLIGHTS

**Water resilience**
The building can stores enough for 4 days during the times of disaster

**Cost reduction**

**Net zero energy** (EPI: 21.5 kWh)
Solar PV panels and other innovative solutions have been used.

**App development**
An app has been developed to aid people affected during a disaster

**Food resilience**
An underground food/medicine storage system has been proposed, for use during disasters - this works on the principle of cooling through wind energy.

**Climate resilience**
Improving the microclimate and strategies to combat climate change

**Net positive water**
8,663 kl of rainwater are harvested per annum, of which only 30% is consumed, and the rest may be contributed to the Public Water Supply system.

**Flexible interiors**
Conversion of the building to refuge shelter during disaster scenario

**Social resilience**
Strategies to ensure well being of people at all times have been proposed.

**100% natural ventilation**
Passive strategies have been used to maximize daylight, in addition to ventilation.

**Low embodied carbon materials**
Use of local, rapidly renewable, recycled and recyclable materials and fly ash-based products

**Disaster resilience**
Resilient to man-made disasters, conflicts, pandemics and natural disasters. 122 people may be sheltered during a pandemic, 209 in case of conflict, and 460 during other disasters.

## INNOVATIONS

Innovative solutions have been proposed that effect a quick conversion of the public / common areas of the building into a refuge shelter, using ingenious systems of furniture that may be transformed to beds, as needed. Furthermore, extra beds have been designed, which may be stored in flattened form, and brought into play when needed. Extra toilets, to serve the community in case of a disaster, have again been proposed - these were inspired by the telescopic drawing rolls that all architectural students use - and can be stowed away, when not needed. In addition, keeping the religion of the area in mind, we have also proposed a system of power generation that we call the "Power of Prayer", which is detailed in a later section.

# 4. TEAM INTRODUCTION

**4.A. Team Name :** En-Circle

**4.B. Name of Institutions :** RV College Of Architecture, RV College Of Engineering, RV University.

**4.C. Competition division :** Community Resilience Centre

**4.D. Team Members and team organization**


Fig. 4 Team members

**4.F. Background of the Institution:**

R.V. College of Architecture (RVCA), established in 1992, as the Department of Architecture in R. V. College of Engineering (RVCE), Bengaluru. The courses offered include B.Arch and M.arch which deal with topics like architectural design, graphic design, interiors, structures and also the integration of modern digital means in the design process. Main RVCE campus offers many undergraduate and post graduate courses including almost all branches of engineering. RV University offers undergraduate courses including B.Sc, B.Com, B.Des, B.B.A, B.A and PG courses including M.Des, M.A and M.Tech.


Fig. 4 RV Group of institutions

**4.H. Industry partner:**

Fiducia | AI Inc. started in Sep'2021 with a vision to deliver traceability and transparency applications for multiple industries by using technologies that give capability to Brand Owners to connect to consumers with their Brands in Physical World, Digital World and Metaverse. Brands can convey their story to their consumers using augmented reality, video and content.

Fig. 5 Fiducia | AI logo

## 4.I. Design Management Process:

Team EnCircle followed an integrated design approach in order to establish a strong interrelationship between all the contests. An orderly schedule was formulated to organize the work efficiently. Weekly meetings with the team were held to update about individual research and debate on design. There were regular discussions with the faculty lead and advisor and their suggestions were evaluated and applied. The members have researched in various disciplines and reached out to people in respective fields of expertise. The team has been communicating with the project partner back and forth, thereby incorporating their feedback.

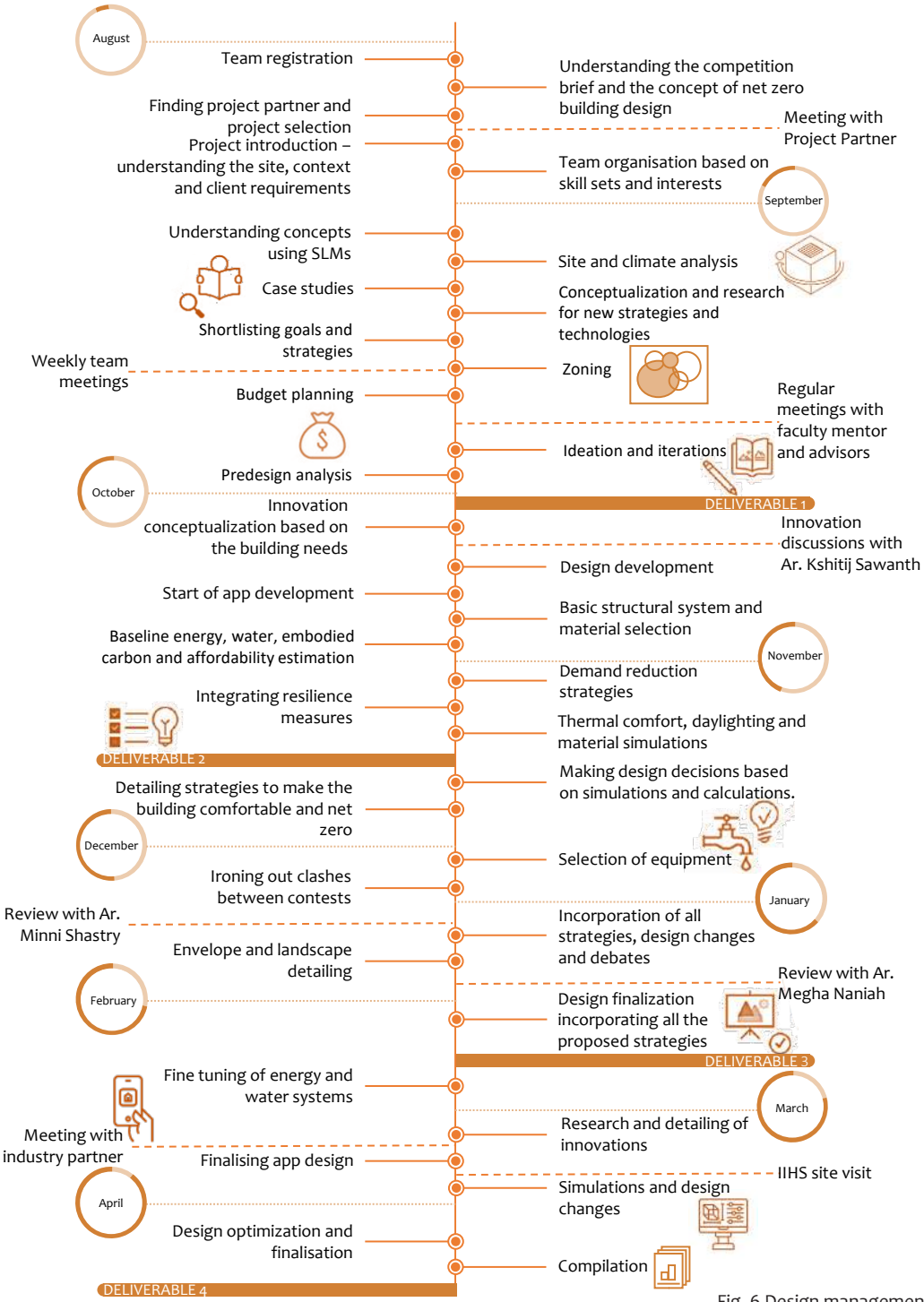



Fig. 6 Design management process

## 4.J. Tools Used:


Fig. 7 Tools used

# 5. PROJECT INTRODUCTION


Fig.8 Satellite image of Itanagar
*Source : Google Earth*


Fig.9 Context plan

**5.A.Project name :** Aikyam
The Sanskrit word "*Aikyam*" , which implies oneness, harmony, and unity, is a good fit with the adage "unity in diversity." To provide a venue for the community, which is seen as the first line of response following a calamity while simultaneously promoting social interaction under regular circumstances.

**5.B.Project partner**: Public Works Department, Arunachal Pradesh. About the project partner: The Public Works Departments, Arunachal Pradesh being the Nodal Agency for premier construction department with presence in all parts of the state The main activities of the PWD are mainly the construction of roads, bridges, RCC Slab Culverts, RCC Hume pipe, CC Drain, retaining walls, and breast wall, buildings both residential and non-residential under the different head of accounts such as RIDF, CRIF, SPA, etc. and maintenance work of all the above heads.

**5.C.Project brief**: The Public works department is responsible for the construction and maintenance of government infrastructure. The region is prone to natural calamities, and owing to the climatic conditions the occupants are at constant risk. To overcome these perils the PWD AP has proposed the construction of an office for the state disaster management officials to monitor and provide relief in the event of any forthcoming danger. It is set within the Civil Secretariat complex of Itanagar, within a site area of 3640 square meters adjacent to the national highway 415(NH415). The intent is to construct an office building that is resilient under all conceivable disaster events. Under normal conditions, the building functions as a government office with related training and public functions, whereas during a disaster apart from functioning as an office it also shelters the affected from nearby areas.
Other buildings situated in this complex include police headquarters, department of public relations, human rights commission and department of rural and urban development.

**Status of the project :** Unbuilt

| Location: Itanagar, Arunachal Pradesh | Latitude: 27.08° N, Longitude: 93.61° E | Climate: Humid subtropical | Profile of occupants: Govt officials & NGO, Village & Voluntary trainees | Hours of occupation: 8 hours |
|---|---|---|---|---|

**engths** - The site is located in the Civil cretariat region, making it easier for local ople to locate in times of disaster since it is andmark. Heavy rainfall helps in rainwater rvesting. Solar radiation allows for the neration of electricity.

**portunities** - Located near the NH415, cilitating with specialized if any during the ne of disaster. The internal and external ads allow for easier accessibility for the cals as well as the office goers. The existing ntours help in drainage without any great ficulty.

S W O T

**Weakness** - There is no existing vegetation on the site and the site is not very green. The state's bylaws only allow a building to be built of a height of not more than 17m.

**Threat** - The site lies in an earthquake zone. There is high humidity. Flash floods are common in the location.

## 5.D.Building use:

**Office**
Whole second floor; First floor – records, server room, visitors room; Ground floor – food court, gym

**Training**
Only education and workshops

**Disaster**
Entire ground and first floor

| | |
|---|---|
| Total site area | 3640 sq.m |
| Max permissible FAR | 2 |
| Max permissible built-up area | 7279 sq.m |
| Max permissible height | 15 m, 17.5m with stilts |
| Proposed total built up area | 4240 sq.m (1.16 FAR) |
| Proposed ground coverage | 43.25% |
| Proposed height | 3.75 x 3 =11.25 m |
| Setbacks | 5 m |
| Occupancy - normal times | Office - 70 people, Training - 112 people |
| Occupancy - disaster times | Refugee seekers – 460, Officers - 70 |

Table i. Building use

## 5.E.Special Requirement by project partner:

- The project partner looks to expand the project by adding a health care facility as an extended program, as a result of frequent natural disasters, compared to the rest of India
- The design should be aimed at achieving as close to net zero as possible
- The project partner looks to achieve a lower cost per sqm in comparison with going market rates without compromising on the efficiency of the building
- The office department in the proposed building is required to continue to function being self sufficient even during disruptions due to natural calamities, therefore being multifunctional.

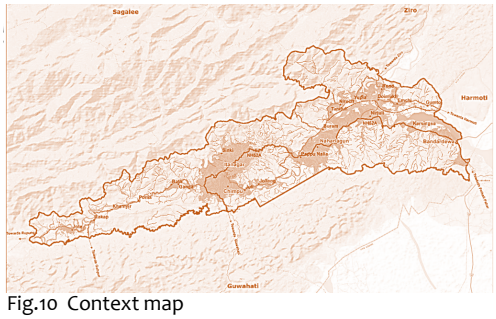



Fig.10 Context map
*Source : Google Images*

**State area:** 83,743 km2
**Capital:** Itanagar is the capital of Arunachal Pradesh, India. known for its scenic beauty, Buddhist culture and heritage.
**GDP:** 9,357 (Rupees in crores)
**International Border:** 1628 kms
**Major Towns:** Itanagar, Naharlagun, Tawang, Bomdila

**Important Minerals**
Dolomite, Graphite, Coal, Quartzite, Limestone, Crude Oil, Natural Gas, Yellow ocher marble

**Natural disaster**
Under seismic zone V and experiences moderate to high risk of hazard with a magnitude 4 - 8.

**Local materials**
Bamboo, straw, stone, clay, cane, adobe.

**Labor:** Mostly works under the supervision of a labor contractor. Wages per person is about Rs. 350 to 400/day according to the PWD AP 2021 schedule of rates.

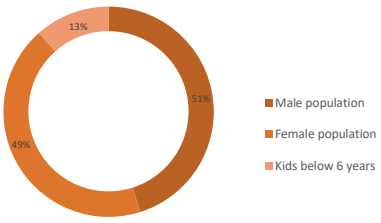



Fig.11 Population

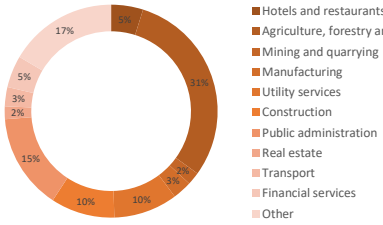



Fig.12 Division of Industries

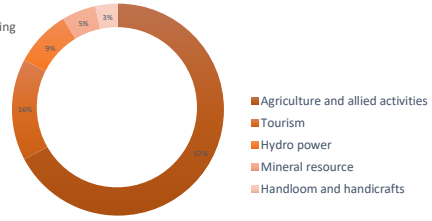



Fig.13 Economy division

**Market potential** : Our proposed building is a multi-functional building. It functions continually as an office department. The training and related public functions are created as per client special requirements as an aiding factor during disaster as well as for community engagement during normalcy. Workshops shall be conducted as per state/national DMA with respect to construction of temporary shelters, first aid and rescue; other helpful skills during disaster.
**Rental opportunity**: The Gym and Bank which had been asked for by the client could be used as a source of income during normalcy. This building pays for itself during normal times, functioning as an office and training center. During disasters however; the training and some public areas have been designed to convert quickly to refuge shelters. A similar program could be replicated across the country if needed. Number of innovations have been proposed - vide the furniture, the toilets and the app towards this end. These have been discussed in detail in section 8.

# 6. GOALS

### ARCHITECTURAL DESIGN

To implement design strategies that help the community during disasters, while still functioning as an office at other times. **(achieved by the architectural design)**


### EMBODIED CARBON

The total embodied carbon emissions of the project to be at least 50% less than the base case. **(68% achieved)**

### INNOVATION

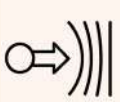
1. Customizable elements that can mold themselves based on user's needs. **(achieved using different kids of furniture and collapsible toilets)**
2. Using peoples' activity to generate power. **(achieved using prayer wheel and gym equipment)**

### AFFORDABILITY

1. Achieving optimal timing for construction. **(24 months)**
2. Minimizing construction cost by atleast 10% **(27.5% achieved)**

### ENGINEERING AND OPERATIONS

1. To establish efficient coordination amongst the various systems **(achieved)**
2. To develop a context specific building structural system and envelope **(achieved)**



### RESILIENCE

1. Improving water-resilience and self sustaining site. **(achieved)**
2. Providing earthquake resilience, pandemic resilience and climate resilience. **(achieved)**

### VALUE PROPOSITION

1. To engage community to prepare them consciously in times of a disaster **(achieved)**
2. Understanding and working with the mindset - perspective of both occupants and investors. **(achieved)**

### ENERGY PERFORMANCE

1. Achieve net zero energy and EPI value of 50 kWh/sq.m annually or less. **(21.5 kWh/sq.m achieved)**
2. To provide energy backup that can sustain the facility for 4 days of disaster. **(achieved)**

### HEALTH AND WELL- BEING

1. Achieve acceptable IAQ as per ISHRAE. **(achieved)**
2. Achieve indoor comfort levels. **(achieved)**
3. Maintaining optimum lux levels. **(achieved)**
4. Promoting the well being of a person under all conditions **(achieved)**

### WATER PERFORMANCE

1. Achieving net zero water and self sufficiency for 4 days during disaster. **(achieved)**
2. Curtailing water consumption for the operation of the building by minimum 50% **(achieved)**

# 7. DESIGN DOCUMENTATION

## 7.A. ARCHITECTURAL DESIGN

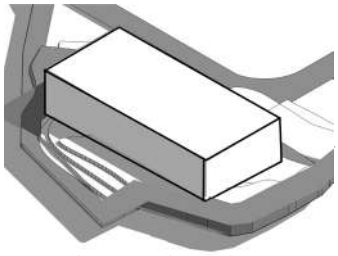


Fig 15a. Orientation

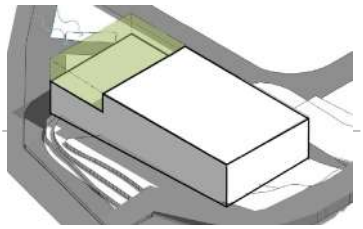


Fig 15b. Stepping, push and pull

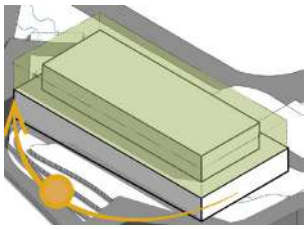


Fig 15c. Solar direction

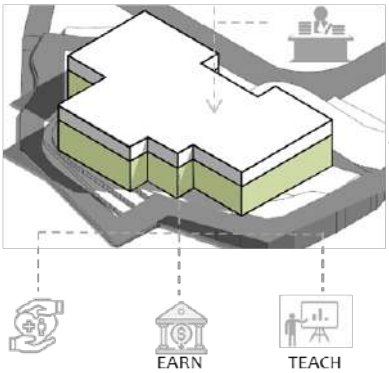



Fig 15d. Zoning

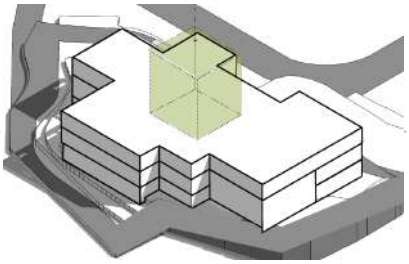


Fig 15e. Atrium

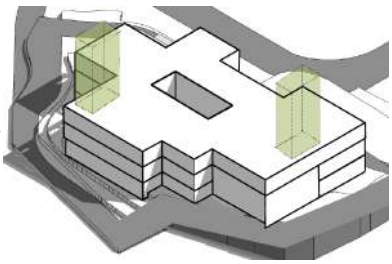
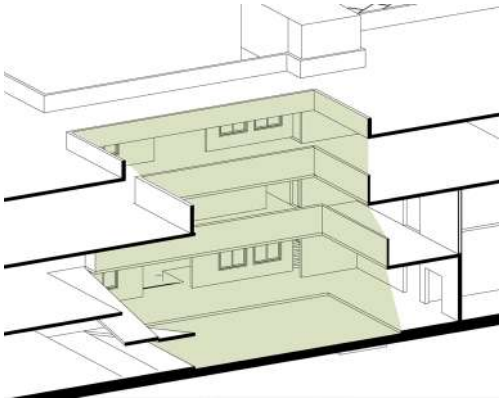


Fig 15f. Vertical circulation

Due to the dual programmatic nature, the building is divided into two vertical zones, with the public functions happening on the lower floors, allowing the office to run without any disturbance and with privacy.



STEPPING AND PUSH-PULL
-Creates an interesting form
-Allows for terraces to be formed on multiple levels
-Helps with terrace gardening
-Breaking the volume
-introduces visual connectivity among the levels.

For providing shade to the large interior spaces

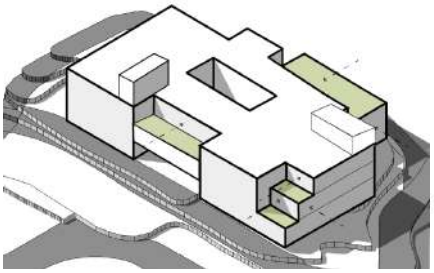
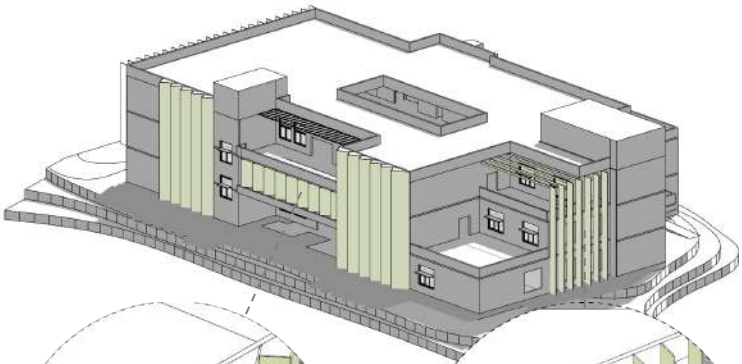


Fig 15g. Terraces



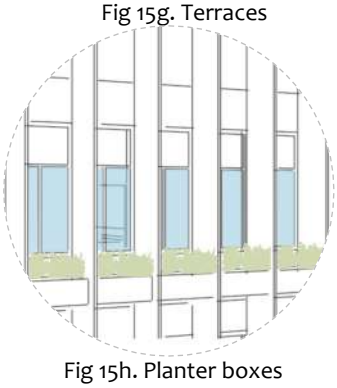


Fig 15h. Planter boxes

Introduce greenery in the site

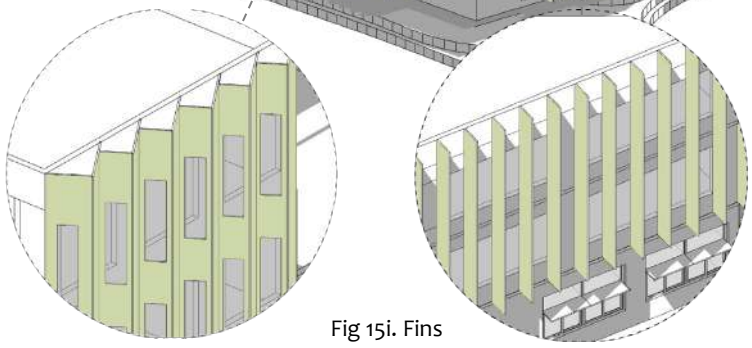


Fig 15i. Fins

Fins and louvres at a calculated angle to properly shade the spaces inside and allow north light directly into the spaces.

ATRIUM

WORKSHOPS

SEMINAR HALL

VIEW FROM FIRST FLOOR LOOKING INTO ATRIUM

OPEN OFFICE

Fig 16d. Views

During normalcy, the building acts as both, an educational community centre as well as an office.

The ground and first floor host leased out spaces for bank and gym and also as spaces where workshops and seminars are held, teaching people how to take precautions and survive if a disaster were to occur as well as how to rescue and aid others. These spaces could also be rented out for community programs.

The top most floor acts as an office for the state disaster management officials to monitor, coordinate and facilitate relief works in the event of any forthcoming danger.


Fig 16a. Ground floor plan

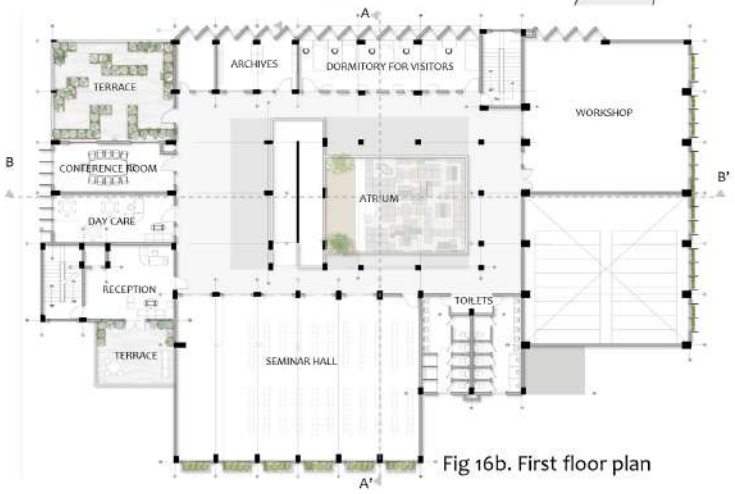



Fig 16b. First floor plan

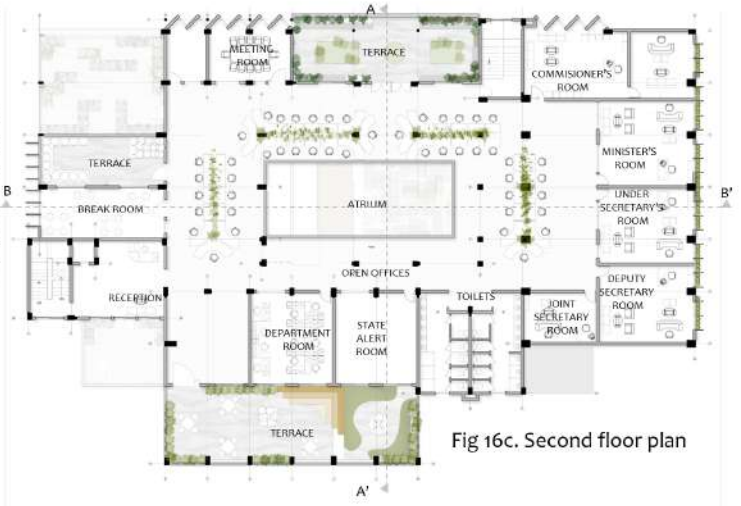



Fig 16c. Second floor plan


ATRIUM


WORKSHOPS


SEMINAR HALL


VIEW FROM FIRST FLOOR LOOKING INTO ATRIUM


OPEN OFFICE

Fig 17d. Views

During the event of a disaster, the building acts as a disaster shelter as well as a functioning office.

Now, the ground an first floor, can house refugees, with the original furniture turning into beds in some places. Some existing stalls in the washroom turn into baths and temporary washrooms, housed in the toilet storage are also brought out.

The top most floor continues to function as an office for state disaster management, helping monitor and coordinate relief works during the disaster.


Fig 17a. Ground floor plan

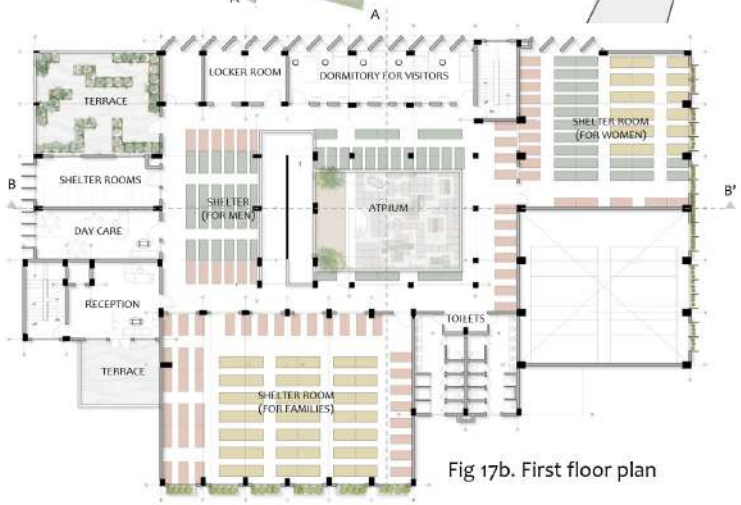



Fig 17b. First floor plan


Fig 17c. Second floor plan

Fins with planter boxes

Office balcony with pergola

Office entrance

Saw tooth wall for north light

Balcony with community garden to grow food

Fins

Fig 18. Interior views

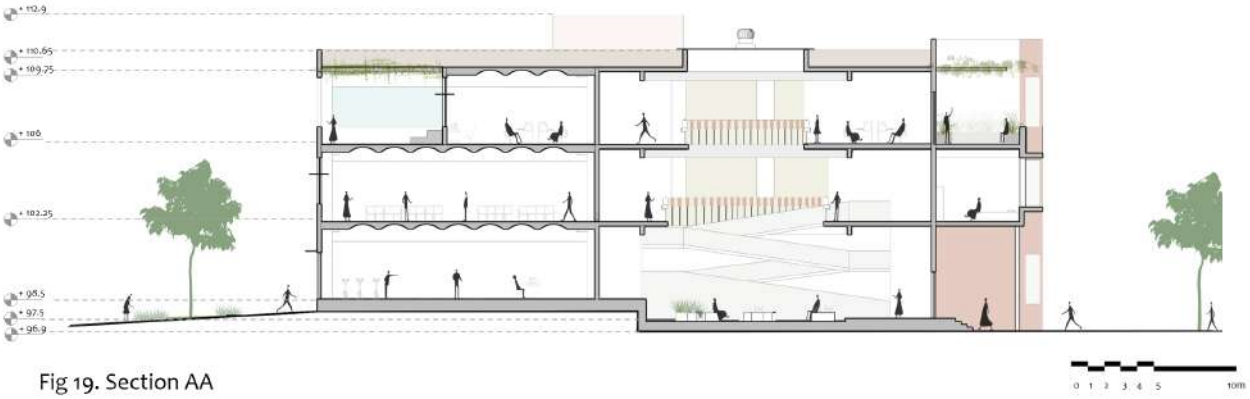



Fig 19. Section AA

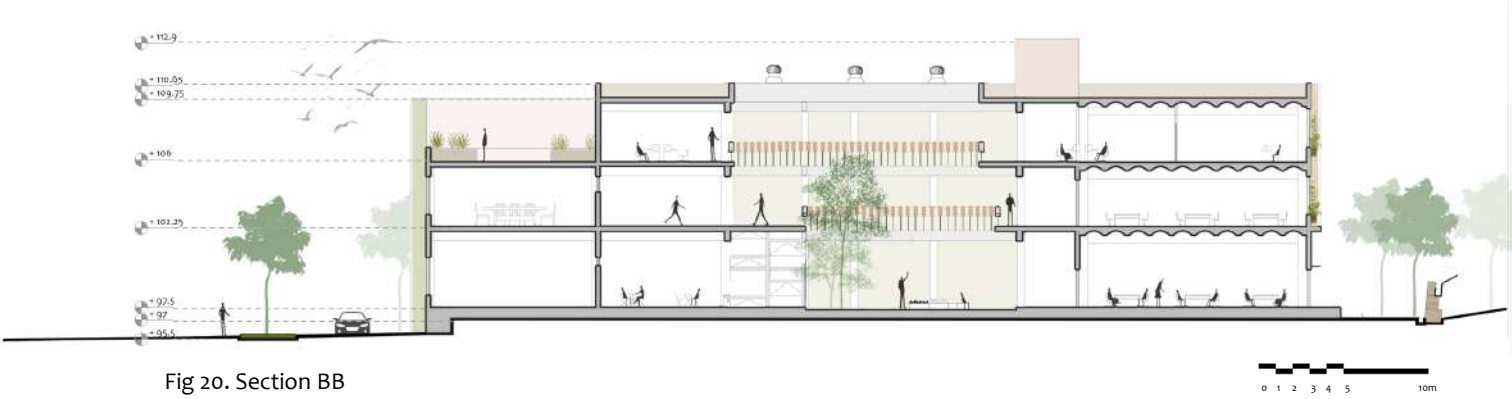



Fig 20. Section BB

## 7.B. ENERGY PERFORMANCE

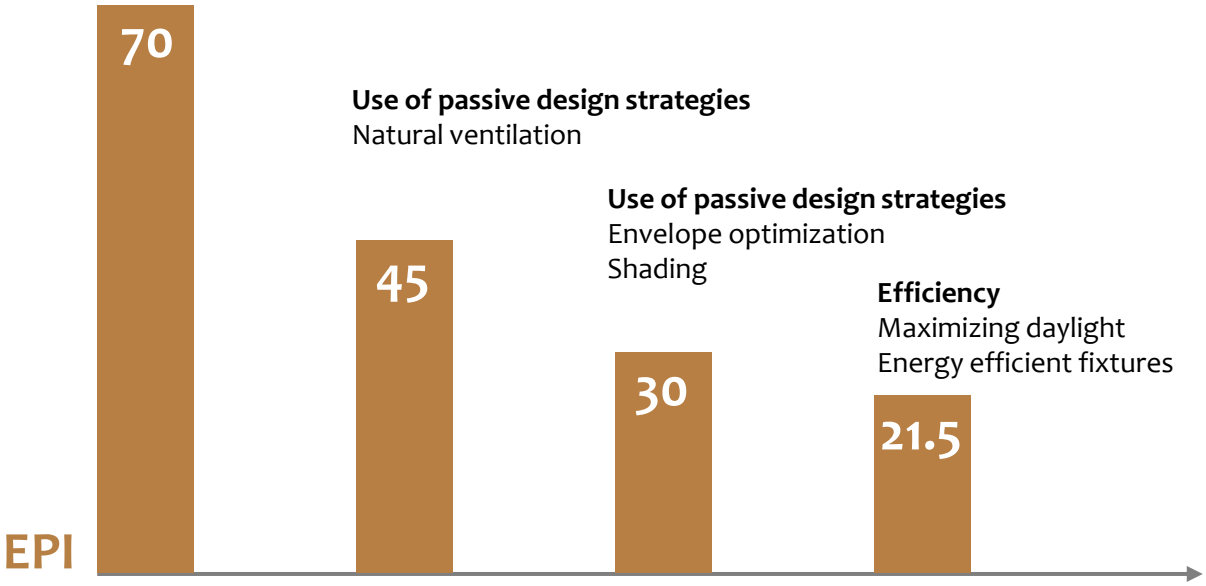



Fig. 21 : Reduction of EPI using various strategies

## BUILDING ENVELOPE OPTIMISATION

Solar radiation simulations helped identify areas of the building that are subjected to excessive solar radiation and heat gain, resulting in discomfort or increased cooling loads. This has been used to design shading devices for each façade to reduce solar heat gain and glare, while allowing for ample daylighting to maximize natural lighting in the building.

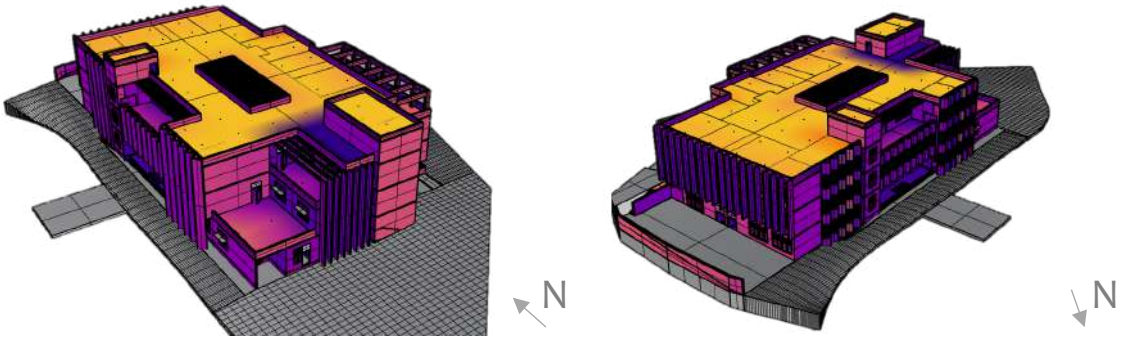



Fig. 22 : Solar Radiation simulation

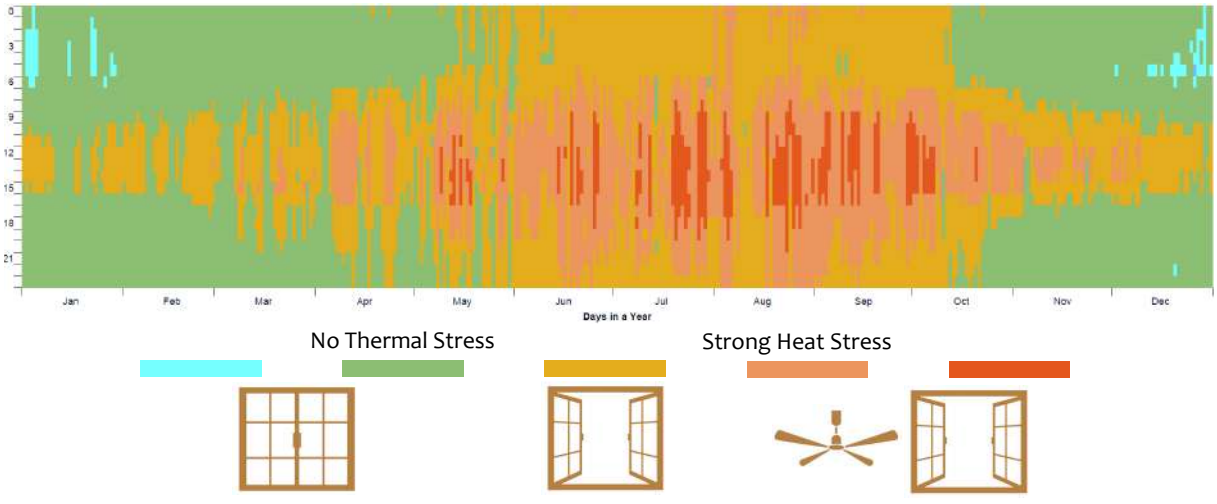



Fig. 23 : Thermal comfort strategies based on UTCI

| COMPONENT | BASE CASE | PROPOSED CASE |
|---|---|---|
| Wall | 200 mm AAC block wall<br>**U-value : 0.31 W/m2K** | 200mm th. Z-shaped Earth blocks with 80 mm air gap and 40 mm Bamboo reinforcement with 10 mm plaster on the interior.<br>**U-value : 0.31 W/m2K** |
| Slab | 150 mm RCC slab<br>**U-value : 1.25 W/m2K** | 150 mm RCC slab with Fly ash concrete, Bamboo reinforcement and recycled steel<br>**U-value : 0.88 W/m2K** |
| Window | 4 mm Clear glass<br>**U-value : 4.8 W/m2K** | Double glazed unit consisting of 2mm Polycarbonate and 6mm air gap.<br>**U-value : 3.6 W/m2K** |

Table ii : Comparison of U-values of materials

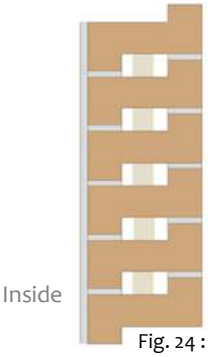



Fig. 24 : Wall Assembly

The walls are made up of Z-shaped Earth blocks, which create an air gap of 80 mm. This air gaps provides insulation and reduces heat gain in summers and heat loss in winters. Although AAC blocks have the same U-value, earth blocks have been considered owing to the embodied carbon content in AAC blocks. For windows, polycarbonate sheets (earthquake resistant) with air gap for insulation have been used for glazing.

## ENERGY EFFICIENT FIXTURES

| LPD | BASE CASE (W/m2) | PROPOSED CASE (W/m2) |
|---|---|---|
| Workshops | 17.1 | 6 |
| Office | 10 | 5 |
| Meeting rooms | 11.5 | 5 |
| Kitchen | 12.1 | 4 |
| Toilets | 7.7 | 2 |
| Storage | 6.8 | 2 |
| Corridors/ Staircases | 5.5 | 2 |

Table iii : Comparison of Lighting power densities

The lighting loads for base case are based on LPD given in ECBC 2017 guidelines for various spaces. The proposed light fixtures are Ceiling Mounted LED Battens of 36W and Ceiling LED Downlight 10W, 100 lumen output per Watt. To enhance air flow along with natural ventilation, fans with BLDC motor have been proposed as they consume 60% less energy compared to standard ceiling fans.
(Refer to appendix for detailed calculations).

| FIXTURE | DESCRIPTION |
|---|---|
|  | Crompton LED Batten 36W,<br>100 lumens per Watt |
|  | Crompton LED Downlight 10W,<br>100 lumens per Watt |
|  | Atomberg Efficio Energy Efficient Ceiling Fan with BLDC Motor |
|  | Atomberg Efficio Energy Saving Exhaust Fan with BLDC Motor |
|  | Wind Operated Turbo Ventilator |

Table iv : Details of fixtures

## SOLAR POWER GENERATION

| LOADS | Annual Energy Consumption(kWh) |
|---|---|
| Lighting load | 18645 |
| Equipment load | 64957 |
| Ventilation load | 7713 |
| **TOTAL** | **91315** |
| Total built up area | 4240 |
| **EPI achieved** | **21.5** |

Table v : EPI calculation with loads

The load calculations are based on a working period of 8 hours for 313 days in a year for a normal scenario and for a period of 4 days during a disaster.
(Refer to appendix for detailed calculations)
The lighting loads have been reduced by 50% as it is met with adequate daylight, SDA = 50%.
The solar energy potential has been calculated for various tilt angles (lat. ± 15°) and an optimum angle of 27° is considered. As per base case calculations, about 68% of energy requirements can be met using solar panels. With the proposed case, 100% can be achieved using solar energy.
Along with solar panels, energy is also generated using gym equipment and the power of prayer – Buddhist prayer wheels.
(Refer to appendix for detailed calculations)

| MONTH / TILT ANGLE | 42.09° | 12.09° | 27° |
|---|---|---|---|
| January | 9503 | 7880 | 8934 |
| February | 8700 | 7744 | 8439 |
| March | 8998 | 8688 | 9156 |
| April | 7361 | 8048 | 7886 |
| May | 6988 | 8225 | 7783 |
| June | 5595 | 6839 | 6353 |
| July | 5951 | 7066 | 6644 |
| August | 7182 | 8205 | 7884 |
| September | 6361 | 6641 | 6660 |
| October | 10234 | 9208 | 9990 |
| November | 9855 | 8117 | 9245 |
| December | 8195 | 6689 | 7654 |
| **TOTAL** | **94924** | **93528** | **96628** |

Table vi : PV panels annual energy generation at different angles

**Solar panel modules**
Capacity : 445 Watts
Efficiency : 17.10%
Dimensions : 2063 x 1026 x 35 mm
Solar Cells: Monocrystalline
Number of cells: 144 cells
Plant size : 80.1 kW
Annual energy generation : 96628 kWh

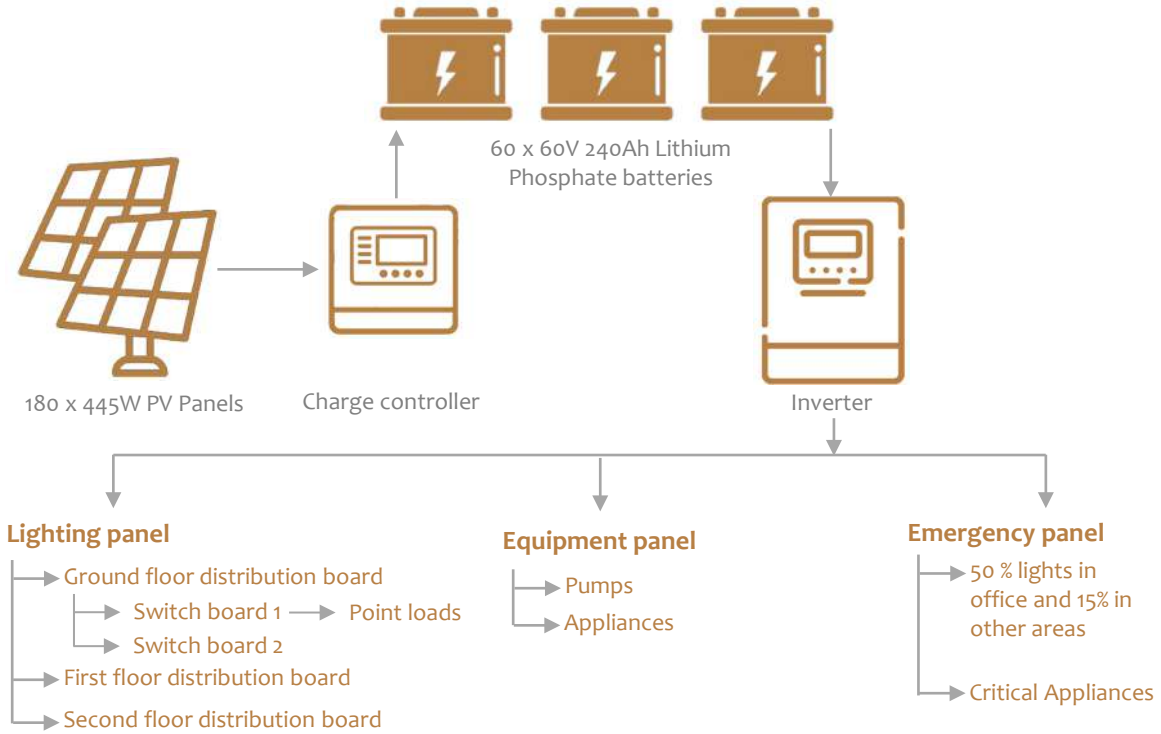


Fig. 25 : Solar power division

## 7.C. WATER PERFORMANCE

### SOURCE OF WATER

The main sources of water for our building are rainwater, municipal water and treated grey water. The region receives an annual precipitation of 91.8mm per annum hence making it the major source of water. **Surplus rainwater** is given back to the grid making it a **net zero positive building.**

Owing to seasonal variations municipal water is taken during the months of November, December, January, February to curb the deficiency. (refer table 2)

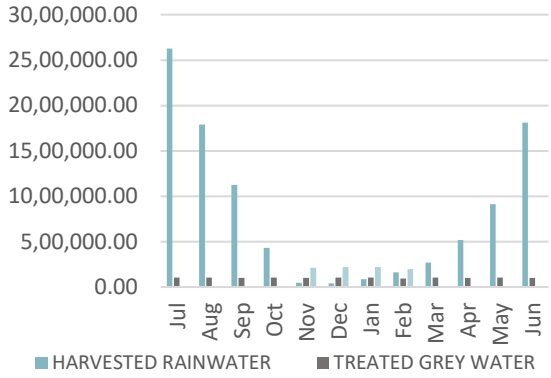



Fig. 26 : Harvested rain water vs. treated grey water

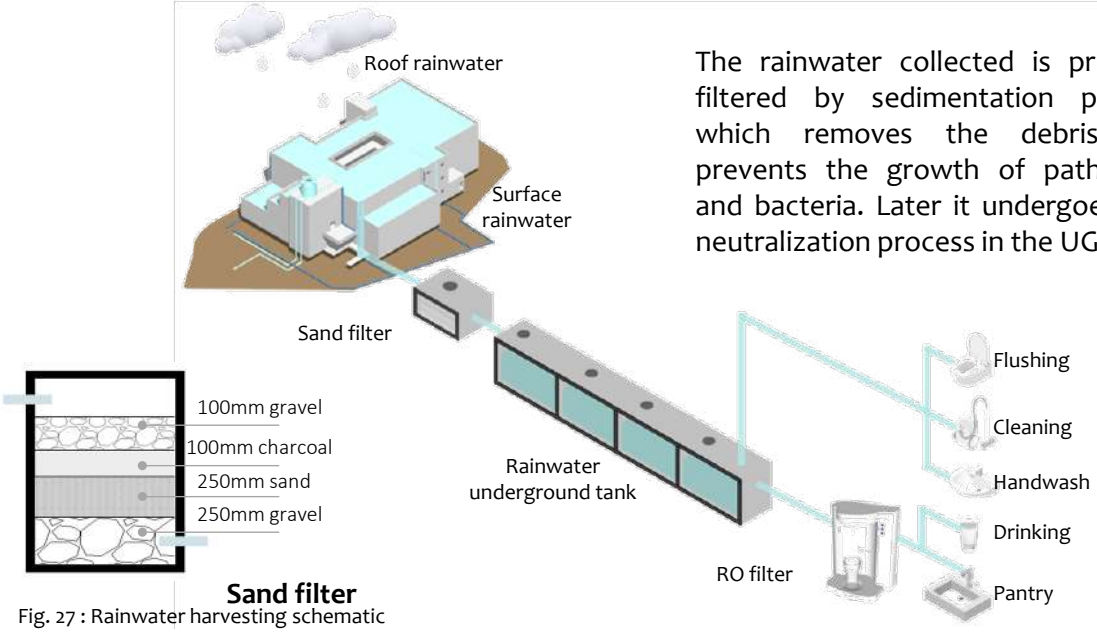



Fig. 27 : Rainwater harvesting schematic

The rainwater collected is primarily filtered by sedimentation process which removes the debris and prevents the growth of pathogens and bacteria. Later it undergoes acid neutralization process in the UGT

### WATER CONSUMPTION AND REDUCTION (BASE CASE VS PROPOSED CASE)

#### NON-DISASTER TIMES

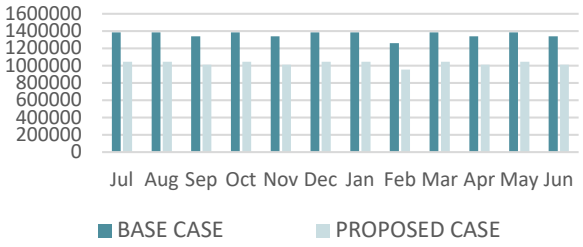



Fig. 28 : Base case vs. proposed case - non disaster times

With the usage of efficient water fixtures the water consumption has been brought down from **45lpd to 25lpd** during normal times (refer table 3,4&5)

**Base case water demand = 52,56,000 lpa**
**Proposed case water demand = 24,54,480 lpa**
**Therefore reduction by 51.2%**

#### DISASTER TIMES

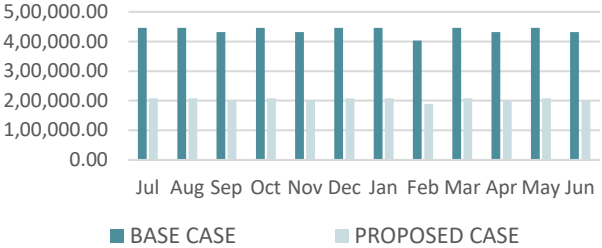



Fig. 29 : Base case vs. proposed case - disaster times

Along with the usage of efficient water fixtures and by rationing water, the consumption has been brought down from **135 lpd to 70 lpd** (refer table 6,7,8 & 9)

**Base case water demand = 1,63,04,760 lpa**
**Proposed case water demand = 1,23,13,308 lpa**
**Therefore reduction by 51.8%**

## WATER TREATMENT AND REUSE

### NON-DISASTER TIMES

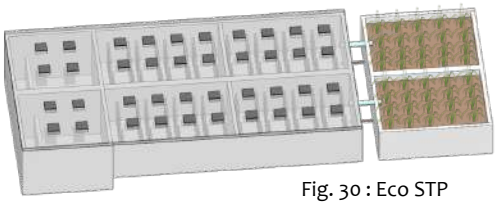


Fig. 30 : Eco STP

**ECO STP** –It is an eco-friendly sewage treatment system which uses **anaerobic bacteria**. It works **independent from power supply**.

Treated grey water is only used for irrigation

**Treated grey water = 12,25,305lpa**
**Irrigation demand = 5,77,221lpa**
(refer table 10)

### DISASTER TIMES

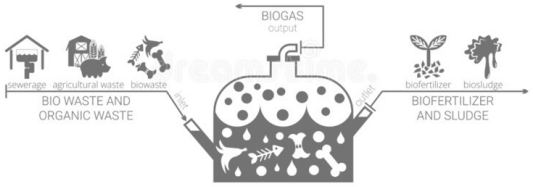



Fig. 31 : Biodigester

**BIO-DIGESTERS** - Human excreta is treated in the holding tank using **anaerobic bacteria**. The by product generated(biogas) is used for heating water during disasters

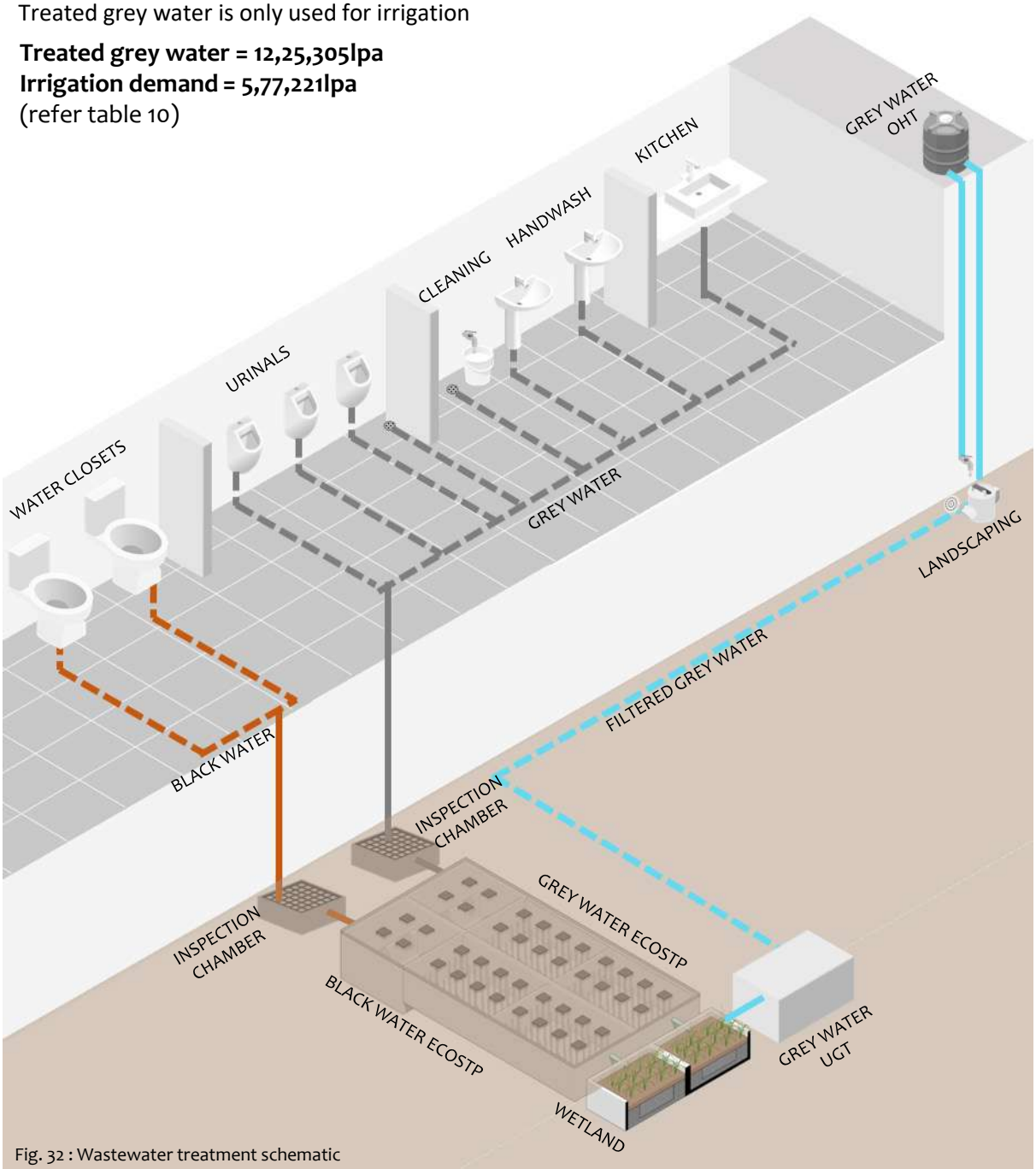



Fig. 32 : Wastewater treatment schematic

| Rainwater harvested 98,20,133 litres/annum | Municipal water 8,52,000 litres/annum | Treated grey water 10,07,400 litres/annum | Water given to grid 72,80,453 litres/annum |
|---|---|---|---|

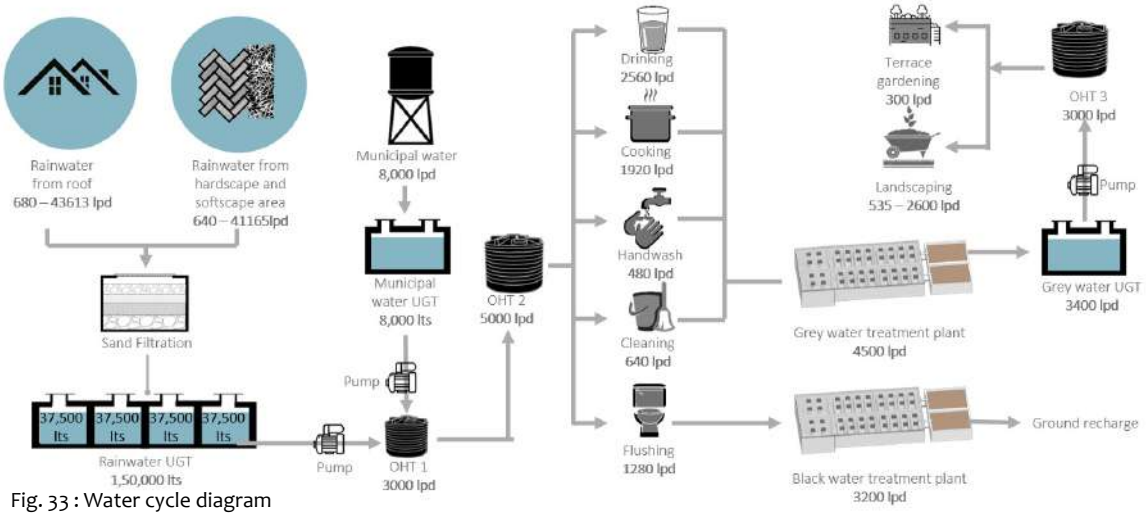



Fig. 33 : Water cycle diagram

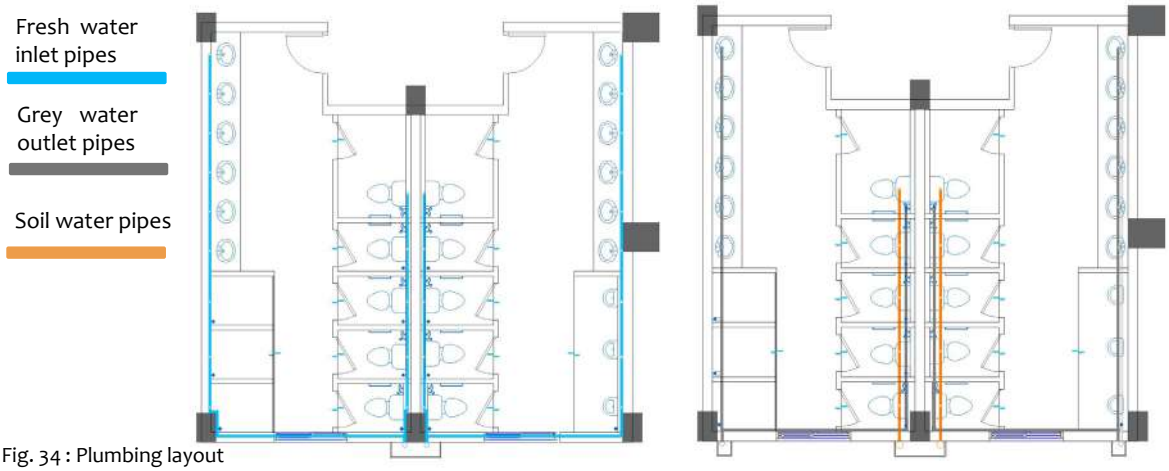



Fig. 34 : Plumbing layout

## OPTIMISATION OF ON-SITE WATER STORAGE

The site has a 1,50,000 lts capacity water tank to provide resilience for 4 days for 460 refugees in the event of a disaster. Water is sent to the municipality grid only after the tanks at site are completely filled, hence providing resilience at all times. So throughout the year water keeps circulating and does not stagnate beyond 3 days

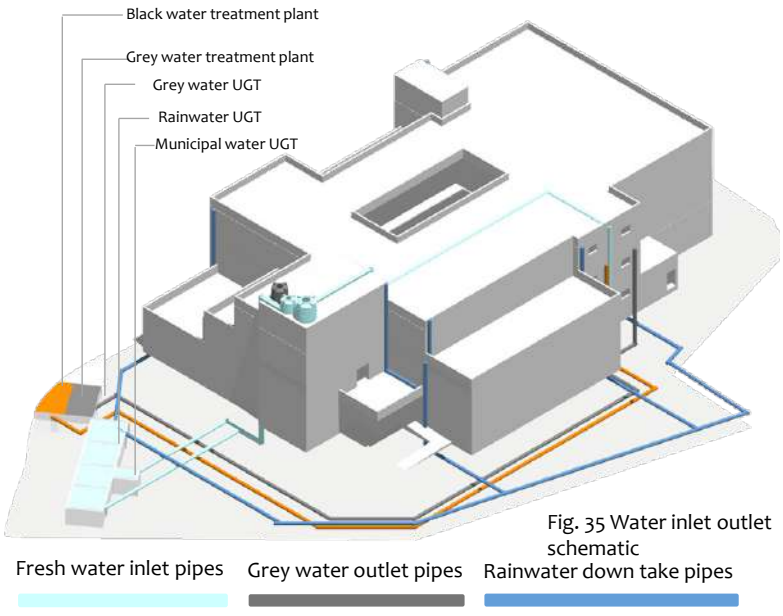



Fig. 35 Water inlet outlet schematic

## 8.D. EMBODIED CARBON

Low embodied carbon materials are an essential component of sustainable construction practices, aimed at reducing the carbon footprint of the built environment. The use of low embodied carbon materials has become increasingly important as the construction industry is responsible for a significant proportion of global greenhouse gas emissions. Using local materials, fly ash-based products, rapidly renewable materials, recycled and recyclable materials we intend to mitigate the impact of climate change and create a more sustainable future.

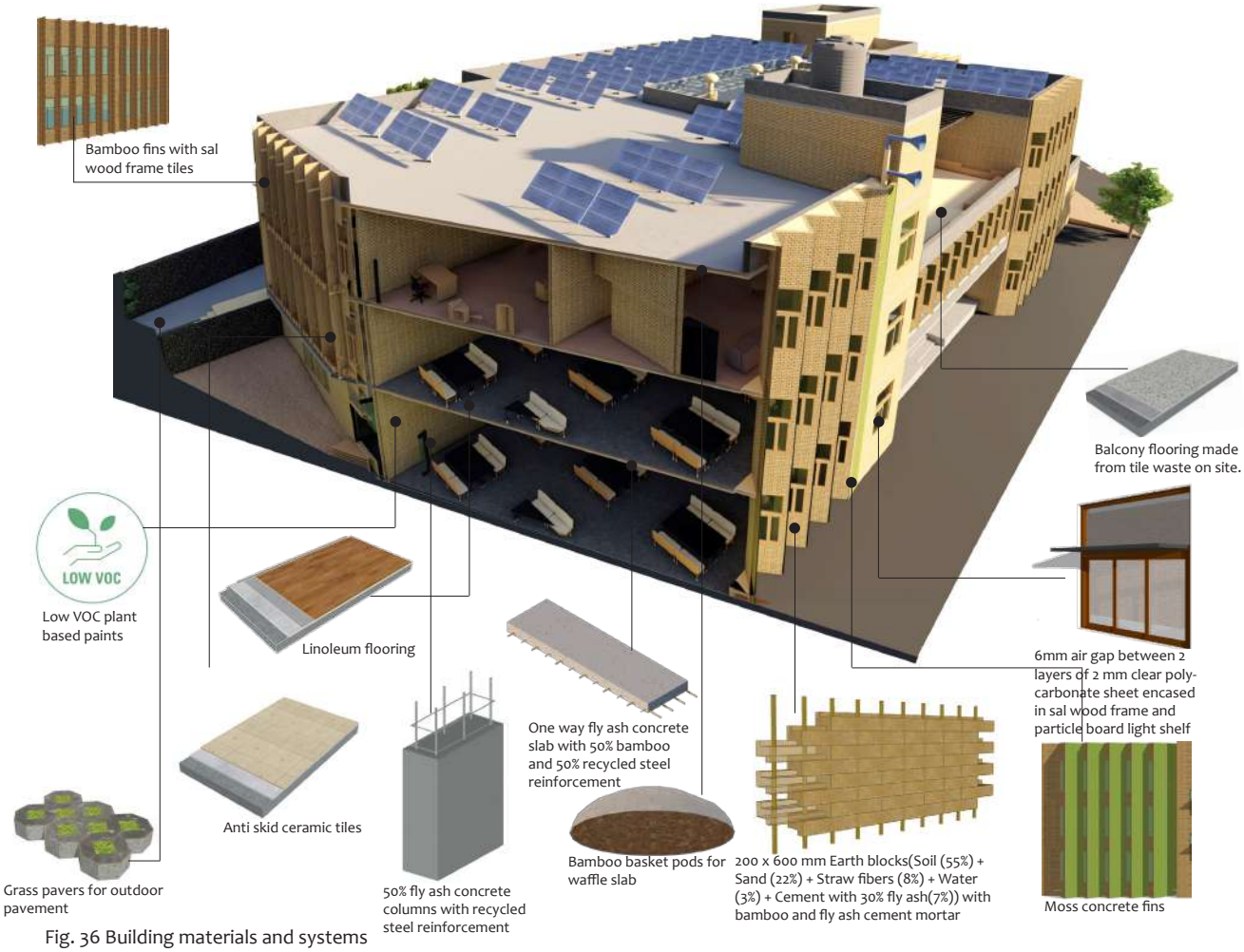



Fig. 36 Building materials and systems

Low impact design approach is achieved by:

Use of locally sourced materials

Use of recycled (steel, particle board) and recyclable materials (steel, earth block, bamboo pods, polycarbonate)

Use of rapidly renewable and natural materials (bamboo, wood).

Reducing cut and fill

Planting 2 sal trees on site or as ICSR for every tree cut for making window frames.

Optimized design mix (fly ash concrete, earth blocks)

Reduction in construction waste in the entire life cycle of the building

Use of less water during construction by use of fly ash based materials and earth blocks.

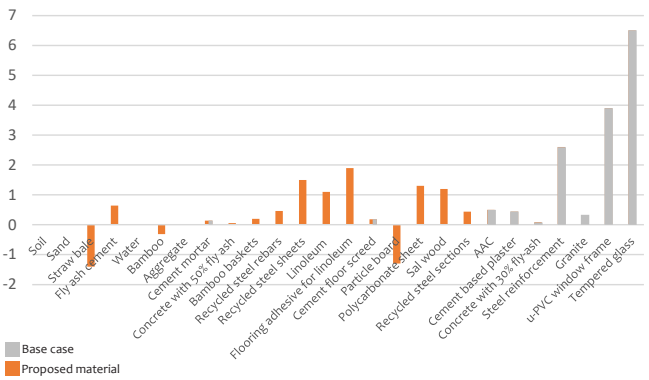



Fig 37 Embodied carbon values

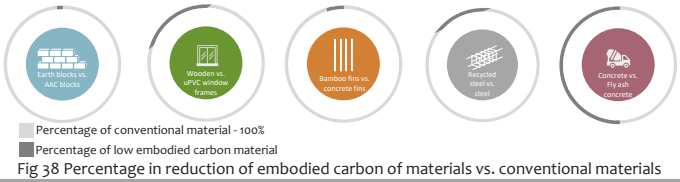



Fig 38 Percentage in reduction of embodied carbon of materials vs. conventional materials

Fig 39 Sourcing of materials

All materials apart from recycled steel are available within 300km radius. Recycled steel is bought from Jindal steel and power, Chhattisgarh, located 1850 kms away from site. Material suppliers are located within 30kms radius from site, hence, reducing the embodied carbon emission due to transportation. (Refer section 9.4 for detailed calculations and embodied carbon summary sheet)

**WALLS - EARTH BLOCKS** - 600 x 200 x 155 mm
Composition – Soil (55%) + Sand (22%) + Straw fibers (8%) + Water (3%) + Cement with 30% fly ash (7%)
Choice of material – Soil contains least amount of embodied carbon and it is available on site. Sand and cement can give it more strength and hence make the block resistant to seismic forces. Straw fibres can act as a binder to hold the different elements together. All the materials are available close to the site, hence reducing the embodied carbon emission due to transportation.

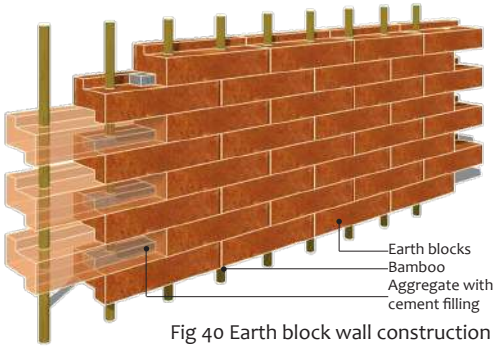


Fig 40 Earth block wall construction

Each block will have two 40 diameter voids for a bamboo insertion which holds the blocks together in case of shear and lateral thrust. 10mm aggregate can be used to secure the bamboo in place.
Mortar - Cement mortar with fly ash

Fig 41 Linoleum flooring

**FLOORING - LINOLEUM SHEETS**
Its flexibility and durability make it a good choice for earthquake prone areas. It is made from natural, renewable materials such as linseed oil, wood flour, and jute which are non-toxic and biodegradable, and hence have a low environmental impact and low embodied carbon which makes it a sustainable choice for building construction and design. It is also easier to maintain, hence reducing the need for harsh chemicals or cleaning agents that can have a negative environmental impact.

**COLUMNS AND BEAMS**
**Recycled steel ties** – To hold bamboo together and provide structural support. According to a 2018 report from the World Steel Association, the average embodied carbon value of recycled steel is 0.46 kg $CO_2$ eq per kg of steel which is significantly lower than that of virgin steel, because the process of recycling steel uses significantly less energy and produces fewer emissions compared to the production of virgin steel.
**Concrete with fly ash** – Fly ash reduced the amount of cement content in concrete. According to a 2018 report by the World Business Council for Sustainable Development, embodied carbon value of concrete with 30% fly ash replacement is approximately 295 kg $CO_2$ eq per cubic meter, while that with 50% fly ash replacement is estimated to be around 200 kg $CO_2$ eq per cubic meter, which is half the value of conventional concrete i.e., 400 kg $CO_2$ eq per cubic meter.

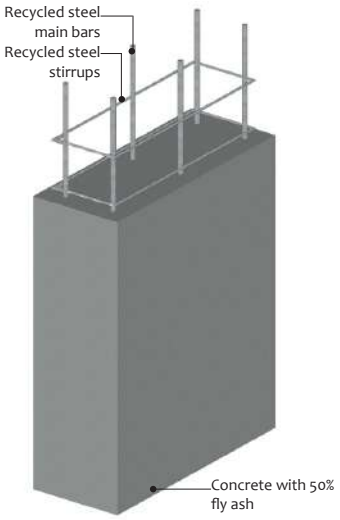


Fig 42 Fly ash concrete column

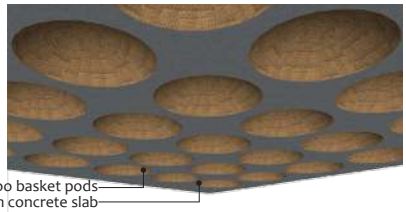


Fig 43 Waffle slab

## SLABS - WAFFLE SLABS AND ONE WAY SLABS

**Waffle slabs** are built using weaved bamboo basket pods, fly ash concrete, bamboo bars and recycled steel stirrups.

**Bamboo basket pods** - Bamboo baskets tend to have a lower embodied carbon value than PVC waffle pods. Bamboo is a highly renewable material that grows quickly and sequesters carbon as it grows. The embodied carbon value of bamboo baskets is estimated to be in the range of 0.1 to 0.3 kg $CO_2$ eq per kg of bamboo, while that of PVC waffle pods is between 1.5 to 2.5 kg $CO_2$ eq per kg of PVC. Exposed bamboo basket pods also brings in the element of vernacularity and aesthetics.

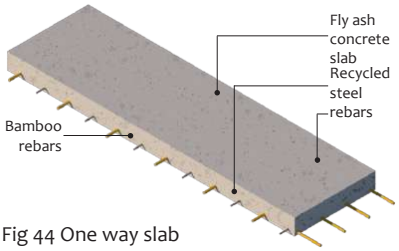


Fig 44 One way slab

**One way slabs -** Recycled steel reinforcement is alternated with bamboo reinforcement to reduce the carbon content and dead load of the slab.

## FENESTRATIONS - POLYCARBONATE WITH SAL WOOD FRAMES

**Sal wood** - It is estimated that the embodied carbon value of Sal wood is 1.1 to 1.3 kg $CO_2$ eq per kg of wood which is lower than that of many building materials like steel or aluminum. However, it's also important to consider the environmental impact of sourcing Sal wood. Hence, twice the number of trees cut will be planted on the site and through social forestry.

Fig 45 Wooden windows with light shelf

**Particle board light shelves with reflective coating** - The embodied carbon value of particle board is lower than that of solid wood, as the manufacturing process for particle board typically involves using smaller pieces of wood that might otherwise go to waste, and the process involves compressing and bonding the wood particles together using adhesives. This process can use less energy and produce less waste than the process of producing solid wood.

**Polycarbonate** - It is suitable for use in earthquake prone areas and has a lower embodied carbon footprint than traditional glass. A life cycle assessment study conducted by the University of Bath and commissioned by the European Union found that the embodied carbon value of polycarbonate sheets ranges from 1.1 to 1.5 kg $CO_2$ eq per kg of material.


Fig 46 Bamboo fins

## FINS - WOODEN FRAME WITH BAMBOO PANEL

**Bamboo** - It is cost effective, sustainable and renewable. Studies from Delft university of technology state that bamboo is a carbon sequestering material with an embodied carbon value of -0.313 kg $CO_2$ eq. It can be easily found nearby, hence reducing embodied carbon emissions due to transportation.

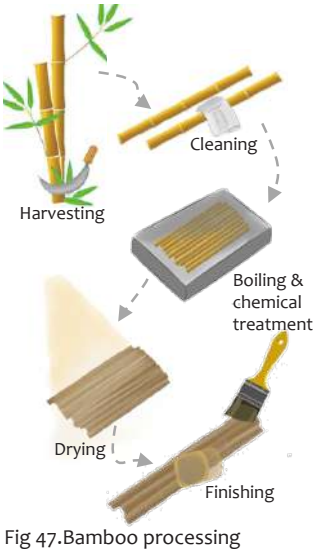


Fig 47.Bamboo processing

**Type** - Bambusa tulda is a fast-growing bamboo species which is known for its strength, durability, and resistance to pests and diseases.

**Source** - The plantation in Chimpu village serves as a source of bamboo and helps in generating income for the locals through the sale of bamboo. Bamboo harvesting and trade are regulated by the local Forest Department.

**Bamboo treatment plant** - Bambusa tulda bamboo treatment is typically done by specialized bamboo treatment plants. One such facility is located in the nearby town of Naharlagun, around 10 km from Itanagar.


Fig 48 Moss concrete fins

**Moss concrete** - It incorporates living moss as a decorative and sustainable element. There is currently limited research available on the embodied carbon value of moss concrete, but incorporating living vegetation into concrete can help to reduce the overall embodied carbon value of the material as plants absorb $CO_2$ from the atmosphere during photosynthesis, which can help to offset the carbon emissions associated with the production of cement.

*(Refer appendix section 3 – material quantities and embodied carbon calculations)*

## 8.E. ENGINEERING AND OPERATIONS

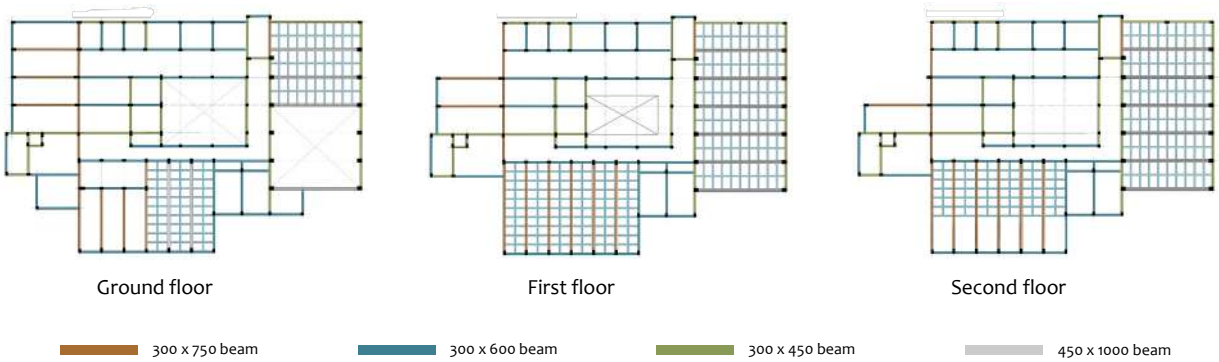



Fig 49. Structural plans with Column position and Beam layout

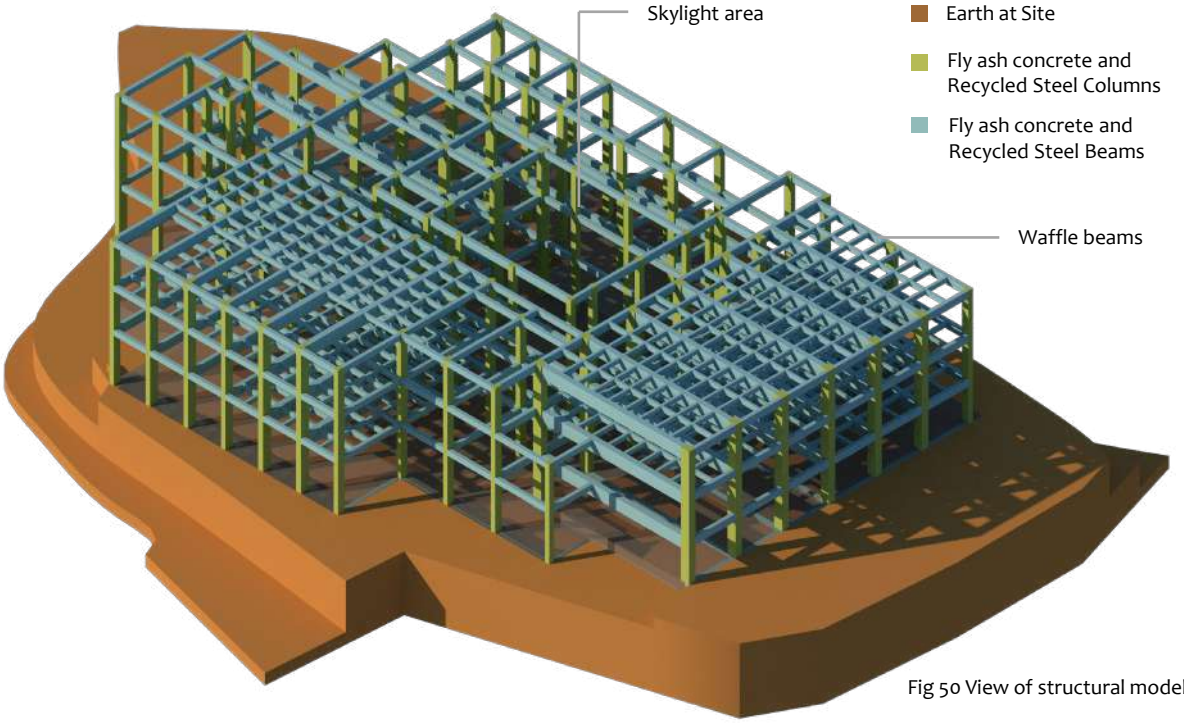



Fig 50 View of structural model

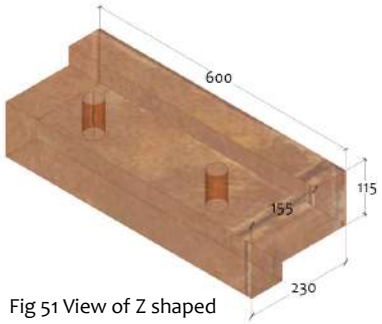



Fig 51 View of Z shaped interlocking compressed earth block

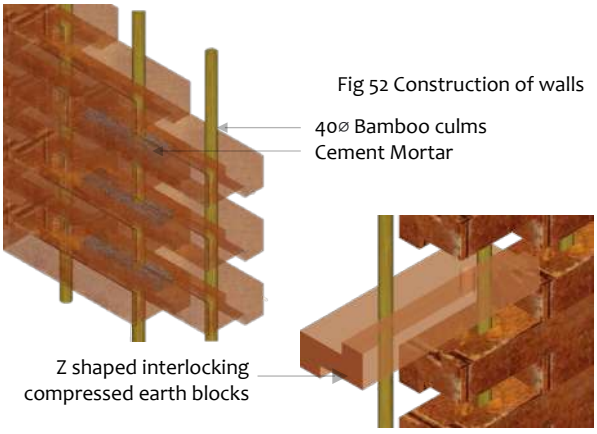



Fig 52 Construction of walls

Other than the interlocking of blocks, bamboo culms gives additional reinforcement by piercing through these blocks

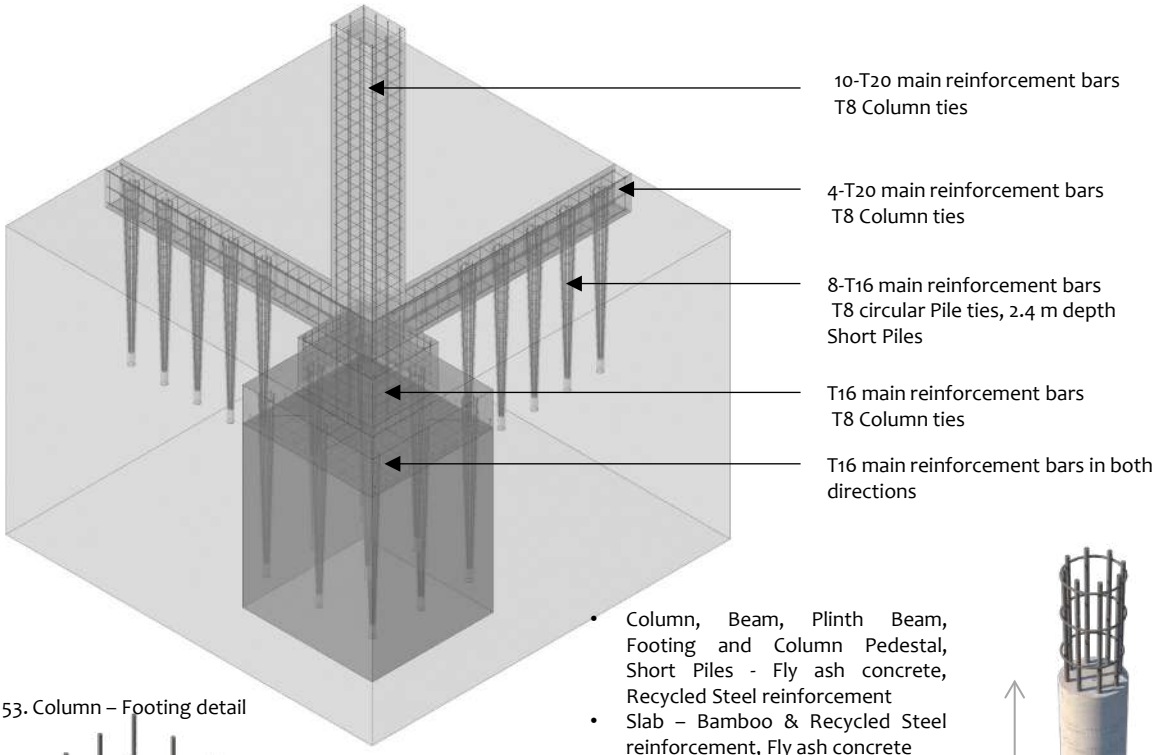



Fig 53. Column – Footing detail

- Column, Beam, Plinth Beam, Footing and Column Pedestal, Short Piles - Fly ash concrete, Recycled Steel reinforcement
- Slab – Bamboo & Recycled Steel reinforcement, Fly ash concrete

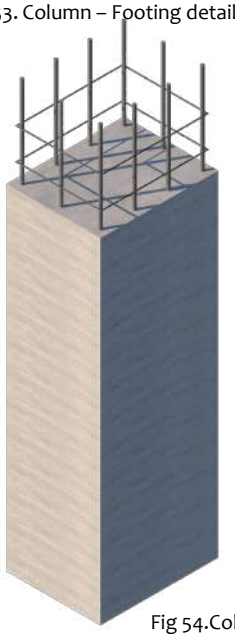


Fig 54.Column View

To make the Concrete mix robust, strong, and environmentally friendly, Fly Ash Concrete is used. The addition of fly ash to concrete improves its crack resistance, which is significant in seismic events. Fly ash also increases the concrete's workability and cohesiveness, allowing for improved consolidation and densification during placement. This results in a more homogeneous and consistent construction that can handle earthquake forces better. As compared to standard concrete, fly ash reduces the rate of shrinkage and creep over time, which can help lessen the risk of structural damage from long-term stress and strain.

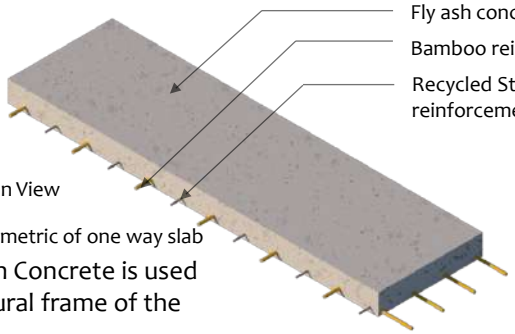



Fig 56. Isometric of one way slab

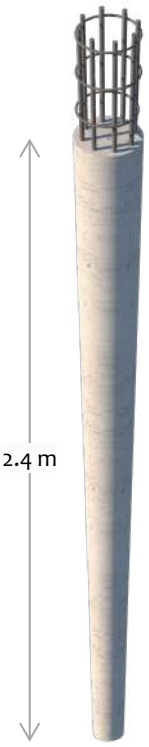



Fig 55.Short Pile View

Recycled Steel and Fly Ash Concrete is used mainly to build the structural frame of the building

(Bamboo Reinforced Slab with Steel as additional reinforcement for Structural strength and cost-economy)

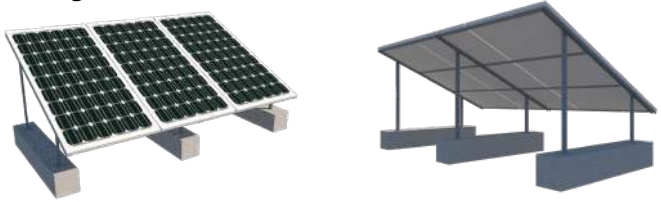


Fig 57. Views of Solar panels supported by recycled steel sections

- Panel size - 2063 x 1023 mm x 35 mm
- Tilt angle - 27 degrees, 144 Cells 445 W each panel

The 27 degree tilt angle strikes a good balance between maximizing solar energy production and minimizing seasonal variations.

## WAFFLE SLAB SYSTEM

Waffle slab system was chosen to avoid columns in the middle of Gym area, Seminar hall area and Office, and also due to their ability to distribute the load over a wide area. Wicker baskets are used as waffle pods as a sustainable and eco-friendly option. It also help to support local artisans and promote traditional crafts and for its unique aesthetic value to the construction project.

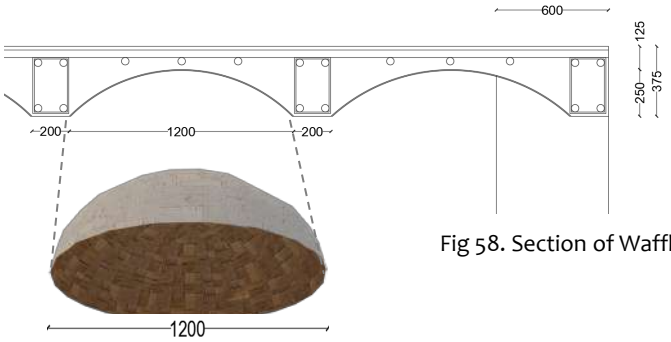



Fig 58. Section of Waffle slab

Wicker basket is coated with a layer of cement paste before pouring
Fly ash concrete to make it non-permeable

## SOLID WASTE MANAGEMENT

| TYPE | MATERIAL | ACTION PLAN |
|---|---|---|
| **NON BIODEGRADABLE WASTE** | Non biodegradable plastic and PVC generated from the building | Collected by waste management facilities equipped with collection, treatment and disposal |
| **BIODEGRADABLE WASTE** | Kitchen waste and landscaping waste | Biodegradable slurry is supplied to bio digestor manually to generate biogas which will be utilized as cooking fuel |
| **RECYCLABLE WASTE** | Cardboard, paper and office waste | Collected by recycling management facilities equipped with collection, treatment and disposal |
| **TOXIC WASTE** | Batteries and E-waste, construction waste | Collected by toxic waste management facilities equipped with collection, treatment and disposal |
| **BIOWASTE** | Sanitary pads, first aid medical waste during disaster times from the gym-converted-field hospital | Collected by medical waste management facilities equipped with collection, treatment and disposal |

Table vii Solid waste management action plan

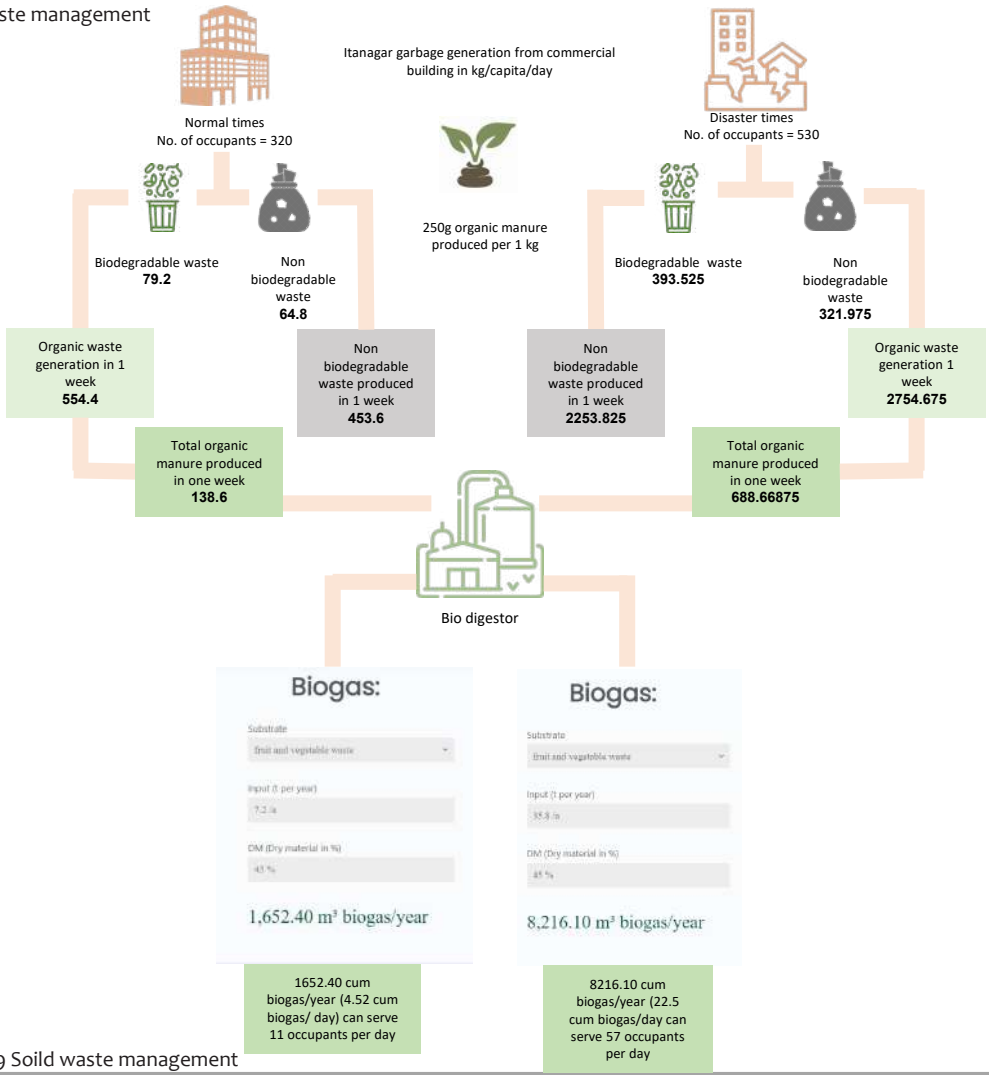



Fig. 59 Soild waste management

# 8.F. RESILIENCE


Fig 60. Resilience cycle

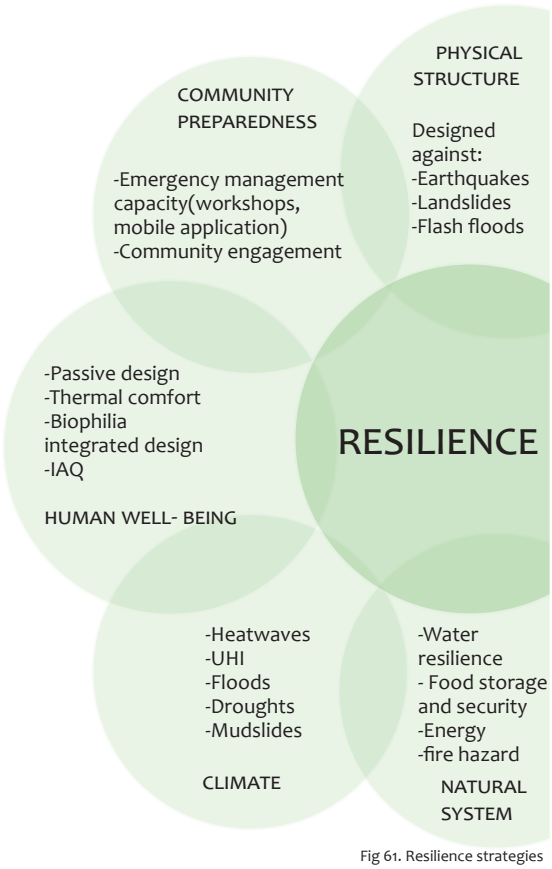



Fig 61. Resilience strategies

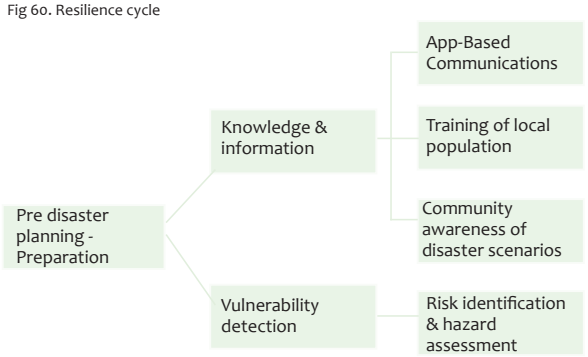



Fig 62. Pre-disaster plan

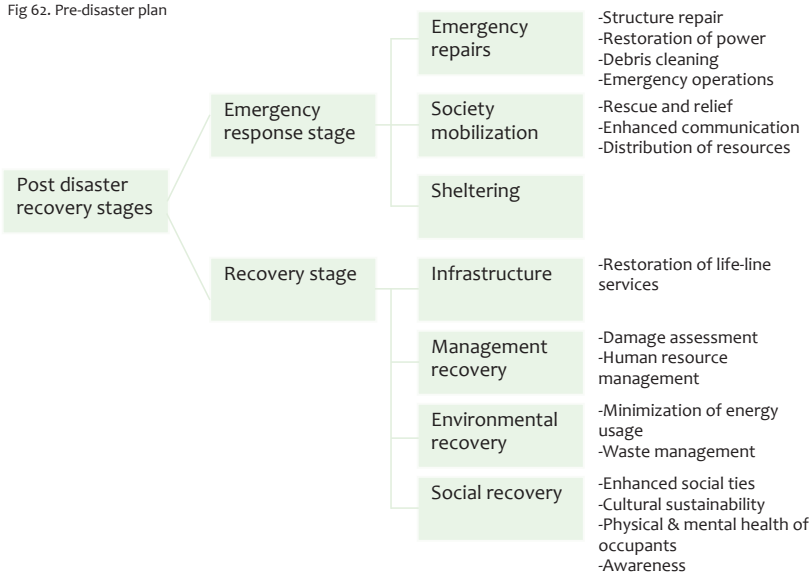



Fig 63. Post disaster recovery plan

The building is flexible and resilient during man-made disasters, epidemics, earthquakes by functioning as a refuge or a field hospital where 460 people are accommodated during a disaster, 209 people could be accommodated during conflict and 122 people could be accommodated during pandemic.
The ground and 1st floor houses refugees, with convertible furniture. The second floor continues to function as an office for state disaster management, helping monitor and coordinate relief works during the disaster.

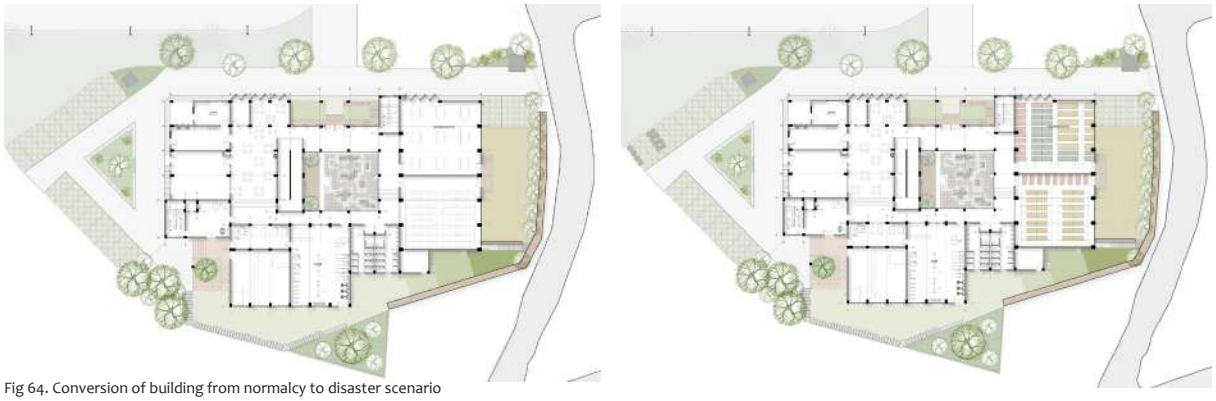


Fig 64. Conversion of building from normalcy to disaster scenario

## EARTHQUAKE RESILIENCE

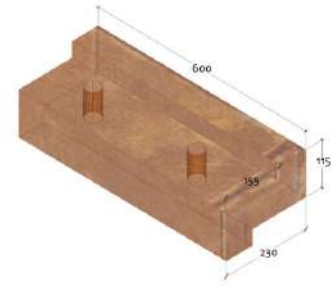


Fig 65. Z-shaped earth block

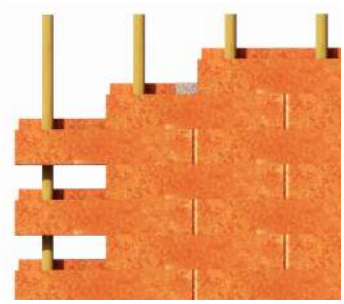


Fig 66. Bamboo reinforced blocks

1. Z-shaped earth blocks: The form of the 600X230X155mm CSEB blocks is designed in such a way that they interlock with each other, thus providing more rigidity to the structure.

2. Bamboo reinforced walls: The CSEB blocks are reinforced with 40mm diameter bamboo which holds the blocks together in case of shear and lateral thrust, thus making the wall strong and steady in times of an earthquake.


Fig 67.Pile foundation


Fig 68.Linoleum flooring

3. Pile foundation: 2400mm deep and 230mm diameter short piles are used to hold the building in place in case of an earthquake. Long piles are avoided since they might break during an earthquake event.

4. Linoleum flooring: It is used for shock resistance during disasters

## CLIMATE RESILIENCE

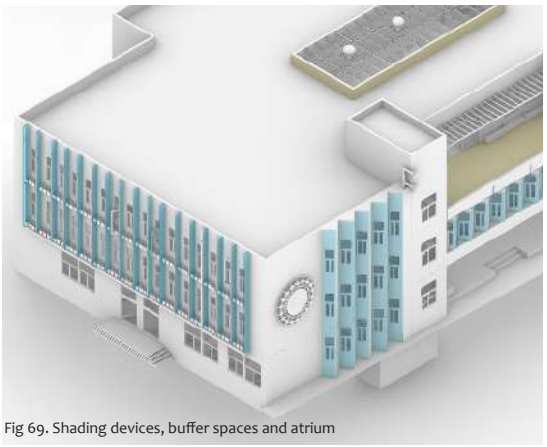


Fig 69. Shading devices, buffer spaces and atrium

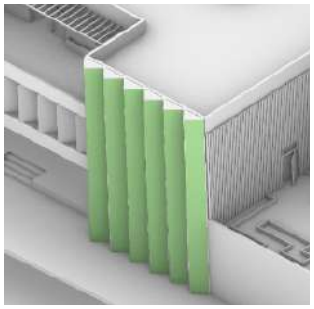


Fig 70. Figure showing moss concrete wall


Fig 71. Vegetation in the site

Resilience against heatwaves could be avoided through passive design approaches like the use of shading devices, envelope optimization, light shelves(that bring in diffused light), terraces(which act like buffer spaces) and stack effect(through atrium). On Northwest, to block the west sun, a sawtooth form has been used with windows facing North. On Northeast, vertical fins have been used to reduce glare in the morning, while on the Southwest, vertical fins are used to reduce glare in the evenings. Visually light materials and colours are used to reduce the heat gain.

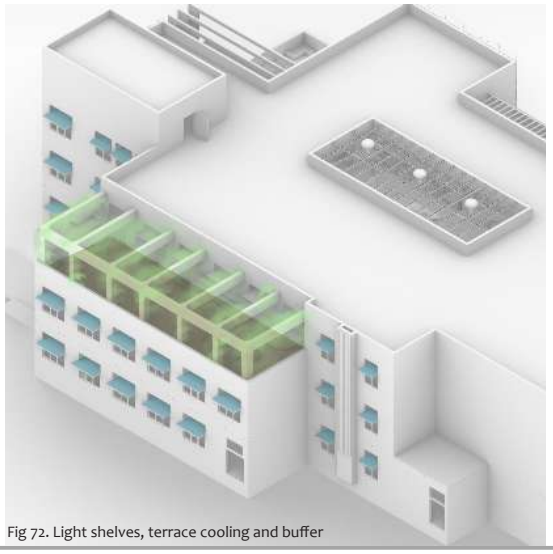


Fig 72. Light shelves, terrace cooling and buffer

Biophilic design with local vegetation is integrated to improve air quality. Moss walls are also used to increase oxygen content. The vegetation also strengthens the soil and prevents mudslides. It can mitigate climate risks by assisting in thermal regulation by providing cooling effects through evapotranspiration and reducing drought and floods through increased soil water retention and absorption.

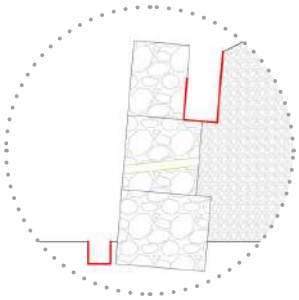


Fig 73. Detail of gabion wall


Fig 74. Elevated site

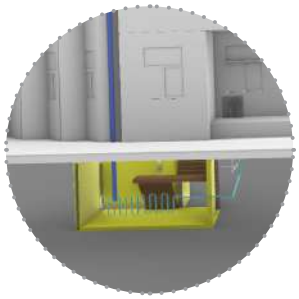


Fig 75. Detail of food storage

Fig 76. Biodigester

Landslide resilience: 3m high and 1m thick gabion wall is provided on the south east side to protect from landslides. 1mX2mX1m baskets are used.
Flood resilience: Site is located at a higher platform to reduce the risk of floods. The planting of vegetation around the periphery also helps to retain excess water in times of floods. The plinth is raised by 600mm and the drainage system is also planned properly throughout the site.

Food security and storage: Rationing of food and water during disaster(storage of rice, pulses, vegetables and medicines (if required) in a storage chamber of 3mX3.5m located below the staircase near the main entry.Food is stored for 530 occupants, for 4 days. Vegetables are grown on site come in handy in times of emergency.

Waste disposal:
The waste generated from the site does not end in a landfill. It is either re-purposed or given to people who will reuse it. Bio digestor is used to generate biogas from kitchen waste which is given back to the kitchen as cooking fuel.

Construction waste and first aid medical waste during disaster that is produced from the field hospital are collected by waste management facilities that specialize in collection, treatment and disposal.

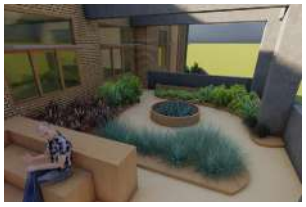


Fig 77. Therapeutic garden view

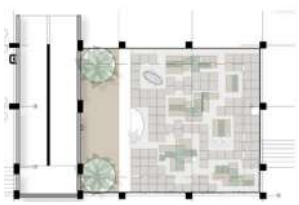


Fig 78. detail of courtyard

Fig 79. Prayer wheel railing

Fig 80. view of community terrace

Fig 81. View of courtyard

Fig 82. Movie screening in courtyard

## SOCIAL RESILIENCE

Certain design strategies have been adapted social resilience which includes people supporting each other socially and building a sense of community. Community and therapeutic gardens are provided for community activities and interaction. Courtyard area with patterned floor for community games.

Prayer wheels are used as an architectural element to promote the belief in almighty which would bring people together. Movie screening also happens(with the energy generated from prayer wheels) in the courtyard area to engage the community.

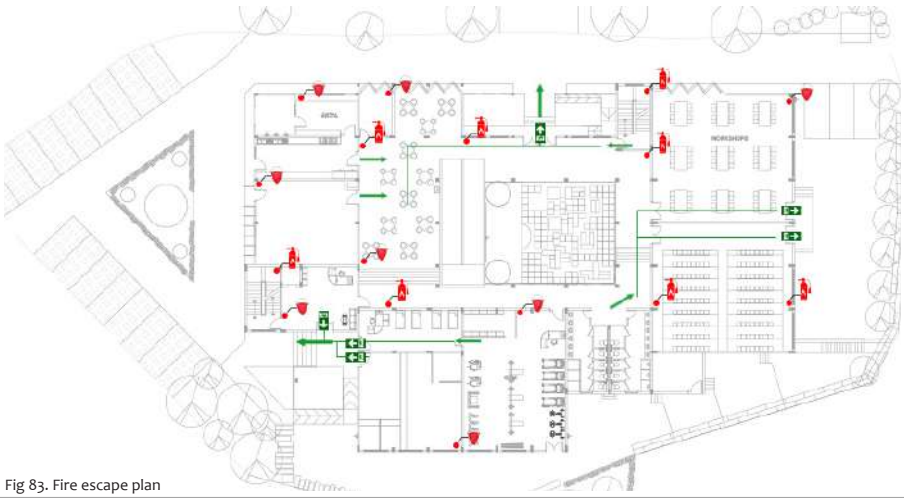


Fig 83. Fire escape plan

## FIRE RESILIENCE

Resilience against fire hazard is provided by the the demarcation of fire escape route. Fire extinguishers, hooters and fire buckets are placed in easily accessible corridors and spaces. Multiple fire exits are provided to avoid the overcrowing of people. 2 hour fire rated doors are provided.

## 8.G. HEALTH AND WELL BEING

The building is designed for **a naturally ventilated operation** . It **is naturally ventilated for 98 % of operational hours assisted with ceiling fans** . This would help in achieving 100% comfortable operational hours for the occupants throughout the year. (As per ASHARE55 ,NBC2016 for warm and Humid climate )

The layout and orientation of the building is optimized for better cross ventilation of usable spaces and operable openings are provided to maximize the air flow movement as well as maximize daylit spaces. To reduce solar heat gain on western and southern facade ,**terraces are introduced which acts as a buffer zones** . The WWR on N,E,S,W facade is 24% , 14.2 % , 22% and 22.5% respectively .

Table viii Area of opening calculation for Double side opening room – cross flow (WORKSHOP )

| Options | Room H | Room L | Room D | Room Volume | ACH | Flow Rate | Wind Velocity | Discharge Coeff | Windward Pressure coefficient | Leeward Pressure coefficient | Minimu mArea of Opening | Area of Opening achieved |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | m | m | m | $m^3$ | ACH | $m^3/s$ | m/s | | | | $m^2$ | $m^2$ |
| | H | L | D | V | ACH | q | U | $C_d$ | $C_{p1}$ | $C_{p2}$ | A | A |
| 1 | 3.75 | 14 | 13 | 682.5 | 12 | 2.275 | 1.3 | 0.6 | 0.1 | -0.1 | **9.22** | **15.45** |

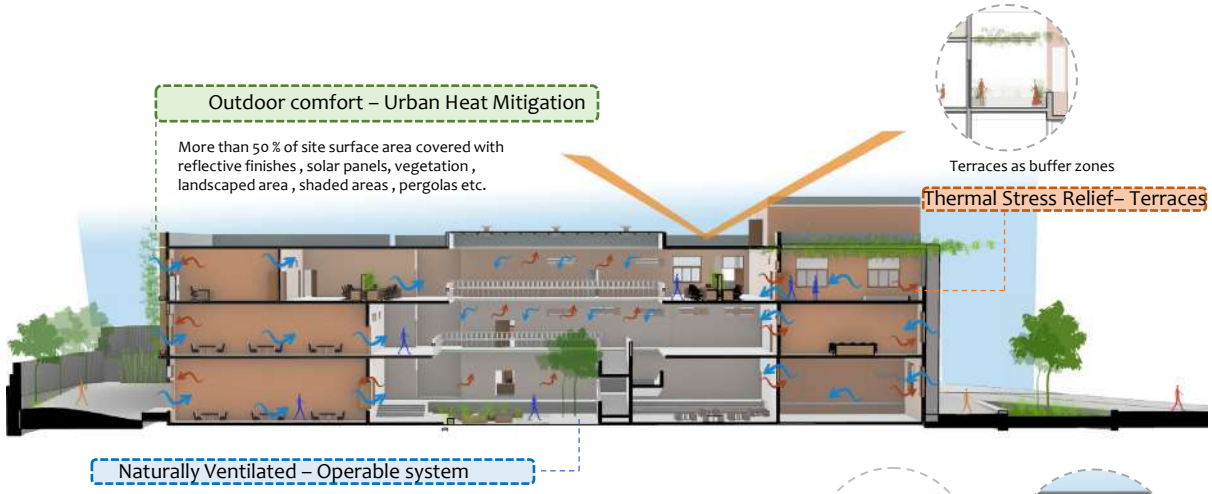



Fig 84. Passive design strategies

The graph shows hourly internal temperature and relative humidity values through out the year. Using algorithms given under NBC, it is found to be **thermally comfortable 98% of the time without the use of mechanical ventilation**

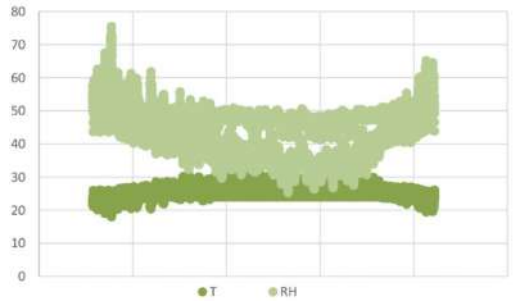
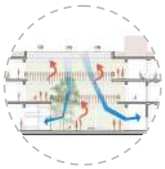



Fig. 85 Hourly internal temperature and relative humidity throughout the year

Effective use of cross ventilation



Stack ventilation

Provision of louvres in interiors

The below graph shows the operative temperature lies within the maximum and minimum temperature of comfort band as per IMAC .

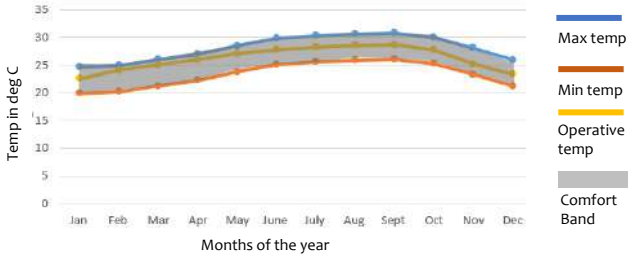



Fig. 86 Graph derived from Simulation data

INDOOR AIR QUALITY

The choice of Low VOC building finishes i.e use of **natural organic paints which has no VOC helps in reducing the $CO_2$** content in the indoor environment in office spaces**. Provision of planter boxes which helps in absorbing the dust, reduce humidity and accelerate air speed.** 12 ACH is maintained for Office spaces (as per NBC) .

VISUAL COMFORT

The different orientations of the building are optimized for maximum daylight by using the appropriate opening size, type and shading devices .Given the requirement of large spans for spaces such as workshops, seminar halls, etc. **light shelves have been used to help penetrate light much deeper.** The light shelf is made up of particle board with metal cladding having 80% reflectivity. The portion above is a fixed window while the portion below is a sliding window. Fins and angular shading in northeast and western façade to **reduce glare and heat gain** .For the visual comfort of occupants **planter box along the façade has been designed in such a way that it is visible from work plane level ,750 mm above FFL.**

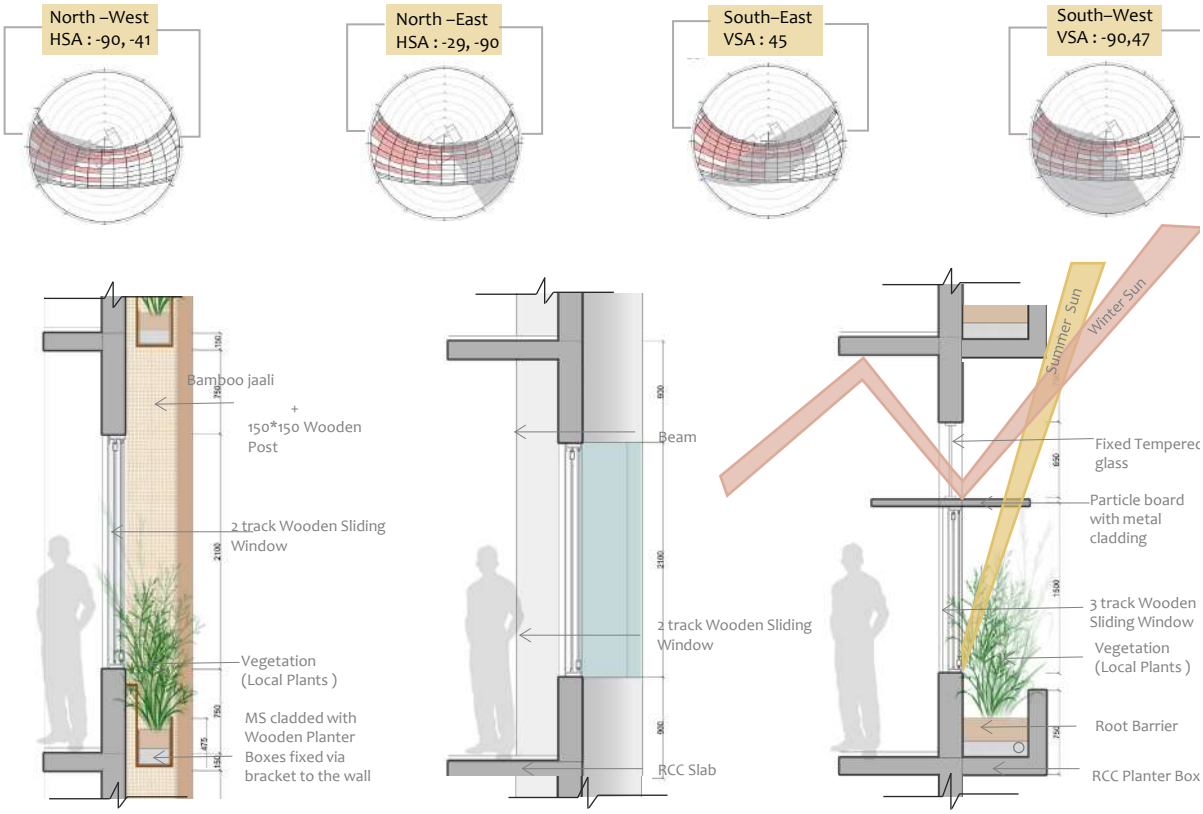



Fig .87 Window detail section :North-Eastern facade

Fig.88 Window detail section : Western facade

Fig.89 Window detail section : South-Eastern facade

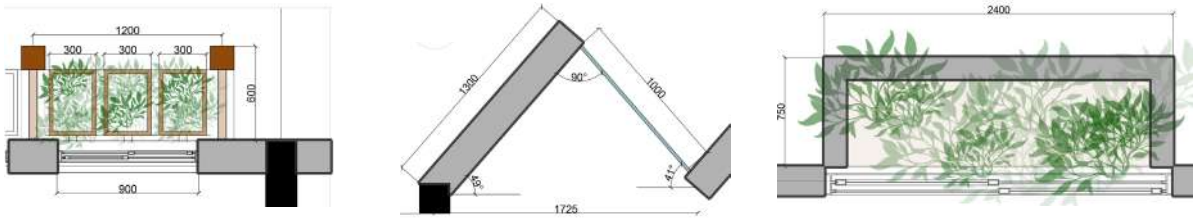



Fig.90 Window detail Plan :North-Eastern facade

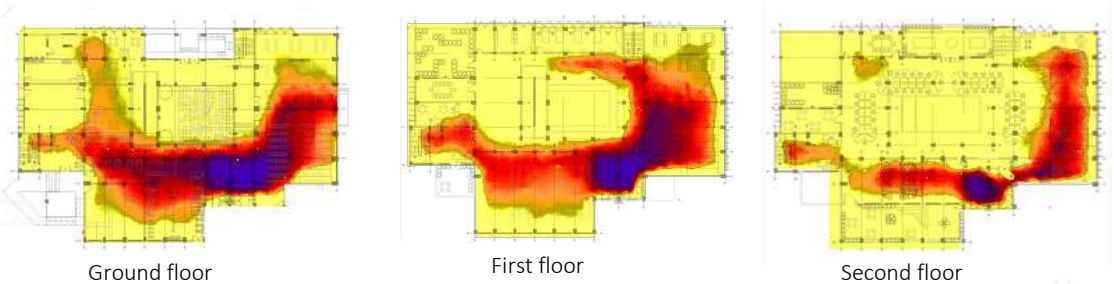
Fig.91 Window detail Plan : Western facade

Fig.92 Window detail Plan : South-Eastern facade

The building connects outdoor flora and fauna by providing adequate views to achieve direct line of sight to vision glazing and uninterrupted view upto 8m to the surroundings ( GRIHA IEQ CREDIT)

As we seen in the simulations ,use of operable windows with light shelves helps to **distribute daylight deeper** and most of the usable spaces can **use maximum daylight** to carry out different functions and activity. The only spaces which does not receive daylight can be addressed by using artificial lighting to meet NBC requirements .


Fig.93 Daylight simulation and day light factor conducted for March with intermediate sky



Ground floor First floor Second floor

SOCIAL AND EMOTIONAL WELL -BEING

Biophilia integrated design is proposed by bringing the outside in –which unifies man-made and natural environments and has the potential to transform the nature of new workspace design by promoting health and wellbeing in office settings.


Areca Palm Schefflera Venulosa Arrowhead Snake Plant Peace Lily

Fig.94 Biophilic aspects

These help in improving air quality and maintain humidity levels providing thermal and visual comfort of the occupants

# 8.H. INNOVATION

## The Power of Prayer

It is natural for all people to beseech the almighty for help during emergencies. Given that a large majority of the Arunachala's are Buddhists, we proposed that the railings in the courtyard area on the first and second floor be constructed using the Buddhist Prayer Wheels. These will function like dynamos, when used, and help generate power for the building. It will also give the refugees a sense of purpose in life during disasters, and dissipate the feeling of hopelessness - specially if they are told about the purpose of the wheels in detail. This idea can be marketed in different areas of Buddhist significance.

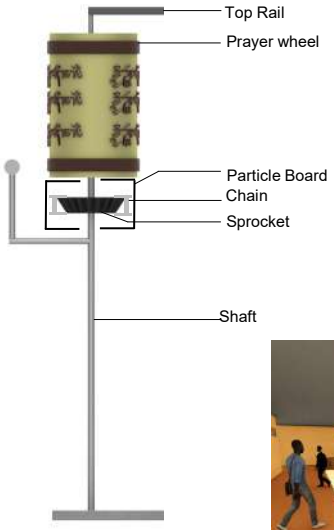



Fig.95 Detailed Section of the Prayer Wheel Railing

***Technology Readiness Level***

Applied research is done and practical application has been found for the prayer wheel setup. Preliminary testing has been established in laboratory environment. (Prototype in progress)

***Innovation Readiness Level***

The prayer wheel railing has been integrated in the design for the intended application. The cost estimates and ROI calculations have been done.

***Costs and benefits***

The proposed innovation has potential to reduce greenhouse gas emissions as it generates electricity for the building. The entire setup generates 50 KWh per year, assuming it runs for half an hour per day, which is enough energy to light a 10 watt LED bulb for 5840 hours. During disaster times, the energy generated using the Prayer Wheel (and gym equipment) is utilized to operate movie screenings in the courtyard to promote social well-being of the refugees. Additionally the presence of prayer wheels add immeasurable emotional value to the project and the refugees in times of distress.(Refer section 9.7 for cost details and energy calculations)

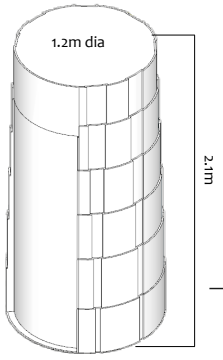
Fig .96 Prayer wheel Railings

## The Roll Toilet

Taking inspiration from an architecture sheet container, the design of the roll toilet consists of six circular sections made of uPVC working on a slide, twist and lock mechanism. The module acts as an enclosure with an attachable door which can be collapsed and stored. The innovation can be marketed to different industries which require collapsible toilet enclosures to save on storage space.

Module size – 1.2 dia x 2.1 m high
Material used – uPVC
Quantity – 24 modules
(18 Indian toilets and 6 western toilets)

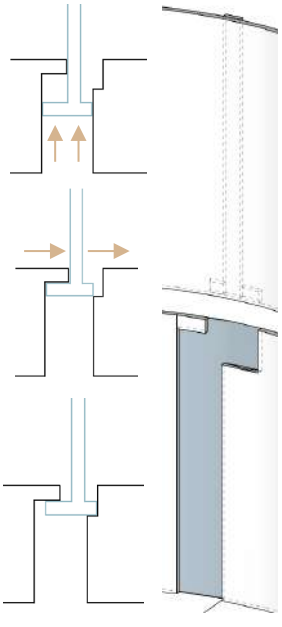
Inspiration




Toilet module when fully assembled

Fig .97 Toilet modules


Toilet module when folded and stacked



Sliding and turning mechanism to interlock the panels

***Technology Readiness Level***

Applied research is done and practical application has been found for the roll toilet. Preliminary testing has been established in laboratory environment. (Prototype in progress)

***Innovation Readiness Level***

The roll toilets have been integrated in the design for the intended application. The cost estimates and ROI calculations have been done.

***Costs and benefits***

The design of the roll toilets is original and solves the problem of storage. Each unit costs 15,000 rupees, and in comparison to a rectangular portable toilet it can be stored in a volume of 0.45 $m^3$ while the other takes up to 2.78 $m^3$ . This means we can store 5 roll toilets stacked on one another in place of 1 rectangular portable toilet.

## Convertible and Collapsible beds

### 1. Refuge Rest

Location: Auditorium

The site has a steep slope on the South-East side, which made it ideal for locating an auditorium on the natural gradient. The seating for 128 people in the auditorium can be converted to 28 beds by folding the backrest back against the higher auditorium step. The auditorium steps, consequently do not follow the standard raking, given the nature of the problem and the need of the project.

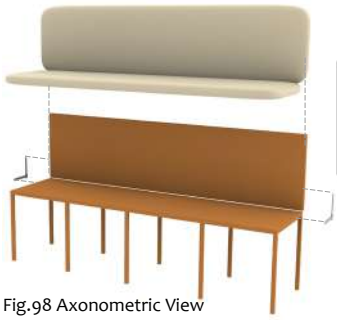


Fig.98 Axonometric View

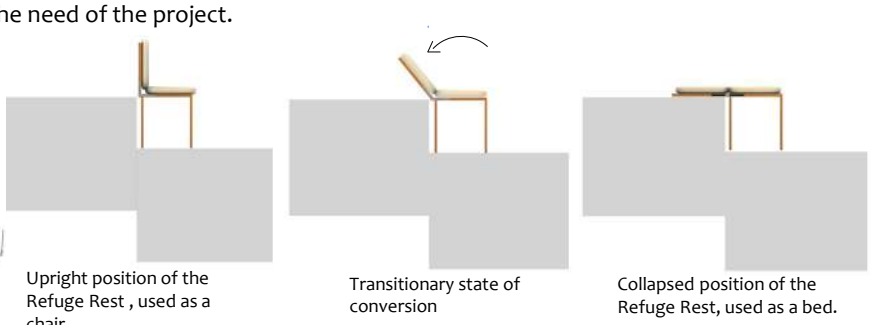



Fig. 99 The process of conversion of the Refuge Rest chair into a bed

Fig.100 Refuge Rest in normal times

Fig.101 Refuge Rest in disaster times

***Technology Readiness Level***

For this innovation, applied research is done and practical application has been found. (Refer section 9.7 for hardware details)

***Innovation Readiness Level***

The Refuge Rest has been integrated in the design for the intended application. The cost estimates have been done.

***Costs and benefits***

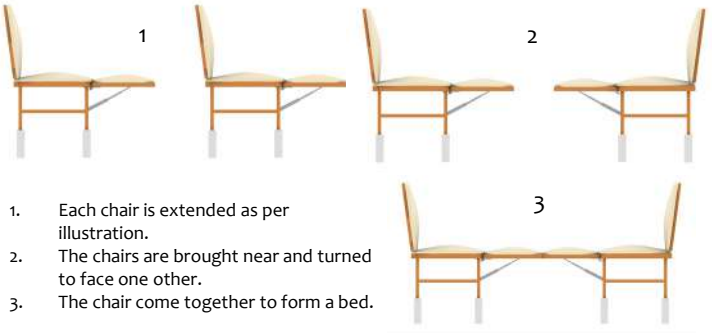
The design of the refuge rest solves the need of collapsible beds required in the project. Each chair costs 44,430 rupees and can to converted into a bed in less than 1 minute.

### 2. Serenity Chair

Location: Workshop

The building will shelter 460 refugees during disaster and hence 460 beds are required. The Auditorium provides 28 beds. The design of the Workshop Chairs evolved due to the need of more beds. The mechanism consists of the pad below the normal chair which can be swung up and locked, and 2 chairs (each 2 seater) in total can be converted to 1 bed. This results in the formation of 82 beds, which are located in the workshops and the small conference room on the first floor. The tables in the workshop will have legs that may be swung up and locked to function as makeshift stretchers in case of need, or stacked flat against a wall, when not needed.

Fig.102 Extension of Serenity chair




1. Each chair is extended as per illustration.
2. The chairs are brought near and turned to face one other.
3. The chair come together to form a bed.

Fig.103 The process of conversion of the Serenity Chair into a bed

***Technology Readiness Level***
The Serenity Chair has applied research done and practical application has been found. (Refer section 9.7 for hardware details)

***Innovation Readiness Level***
The Serenity Chair has been integrated in the design for the intended application. The cost estimates have been done.

***Costs and benefits***
Each Serenity Chair costs 64,050 rupees. The design of the chair provides convertible beds which can be assembled within 5 minutes (considering maximum distance between two chairs in the workshop).

Fig .104 Serenity Chair converted to beds during disaster times

**3. Oasis Bed**

Inspired by architecture students sleeping on mill boards, the idea of bunk beds made out of cardboards was proposed. These have been used before, most notably at the BIEC, Bangalore, during Covid times, but not as Bunks. The Auditorium and workshop provide 28+82 = 110 beds. We have proposed 82 beds of this category, which can sleep 164 people. These beds can be stored flat, under the stage of the Seminar Hall (First Floor), or in the Store Room (Ground Floor), and deployed when needed. We then proposed 186 inflatable mattresses which can be kept on the floor, near the other beds, for use by the last few refugees. This brings us up to the committed number of 460. The flooring in the building will be marked with coloured linoleum, which will look like a design element during normal times, but in time of emergency, can serve as a marking for quick bed deployment.

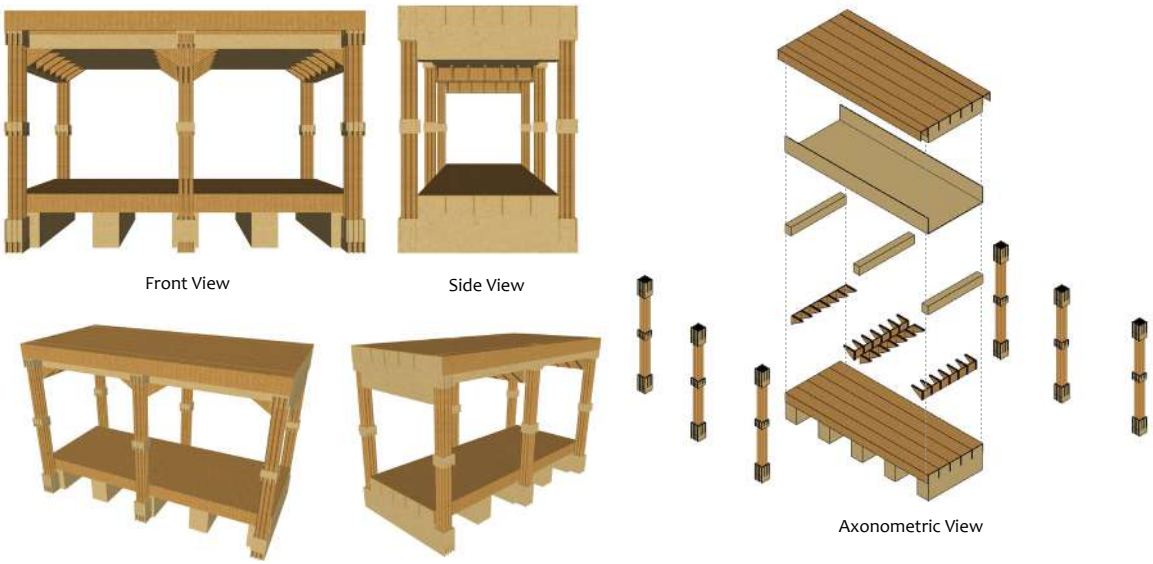



Fig .105 Oasis bed details

***Technology Readiness Level***
The technology of oasis bed is in basic research. The details of its various parts has been worked out which are all made using 12mm, 2mm and 6mm thick cardboard.

***Innovation Readiness Level***
The Oasis Bed has been integrated in the design for the intended application. The cost estimates have been done.

***Costs and benefits***
The design of the Oasis Bed provides collapsible beds which are completely made of cardboard making them lightweight and easily portable. Each bunk bed costs 12,595 rupees which is much cheaper than its counterparts. In the present market, average wooden bunk bed of similar dimensions costs 37,000 rupees which is 34% costlier. The Oasis Bed can further be dismantled and stored in much lesser space than a wooden bunk bed.

# 8.I. AFFORDABILITY

| S.No. | Particulars | Baseline Estimate (Project Partner / SOR basis) | | | Proposed Design Estimate | | |
|---|---|---|---|---|---|---|---|
| | | Amount | % | Amount (INR per sqm) | Amount | % | Amount (INR per sqm) |
| 1 | Land | Not available and not considered for both cases | | | | | |
| 2 | Civil Works | 54,613,640 | 60.50% | 24801.83 | 62,000,334 | 49.67% | 14804.28 |
| 3 | Interior Works | 25,668,411 | 28.43% | 11656.86 | 33,992,336 | 27.23% | 8116.60 |
| 4 | MEP Works | 8,192,046 | 9.07% | 3720.28 | 23,391,042 | 18.74% | 5585.25 |
| 5 | Landscape & Site Development | 655,364 | 0.73% | 297.62 | 3,027,727 | 2.43% | 722.95 |
| 6 | Contingency | 600,750 | 0.67% | 272.82 | 1,816,636 | 1.46% | 433.77 |
| | **TOTAL HARD COST** | **89,730,211** | **99.40%** | **40749.41** | **124,228,075** | **99.51%** | **29662.86** |
| 7 | Pre Operative Expenses | - | -% | - | - | -% | - |
| 8 | Consultants | - | -% | - | - | -% | - |
| 9 | Labor cess | 546,136 | 0.60% | 248 | 605,545 | 0.49% | 144.59 |
| | **TOTAL SOFT COST** | **546,136** | | **248** | **605,545** | | **144.59** |
| | **TOTAL PROJECT COST** | **90,276,347** | | **40,997** | **124,833,620** | | **29,807** |
| | **BUILT UP AREA (IN SQM)** | | | **2,202** | | | **4,188** |
| | **PROPOSED TO BASELINE %** | **72.7057** | | | | | |
| | **DIFF FROM BASELINE %** | **27.2943** | | | | | |

Table ix. Base case vs Proposed Case Cost Estimate ( Refer appendix for detailed calculations)

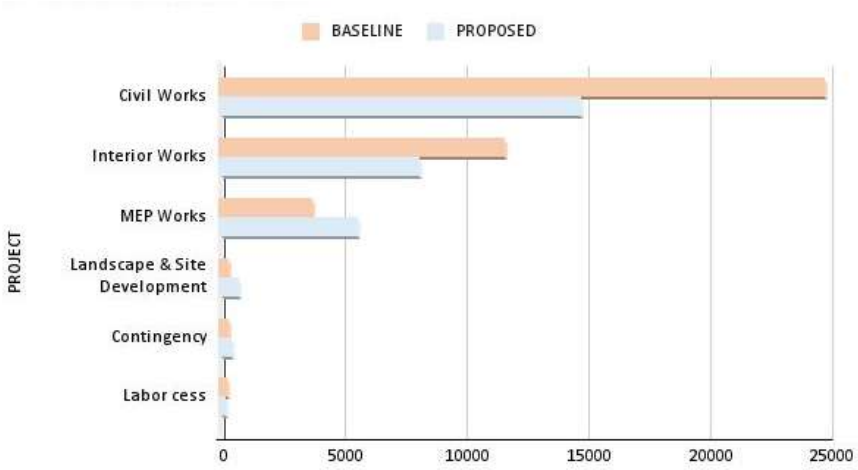



Fig. 106 Cost per sqm sorted by Category of Construction comparison

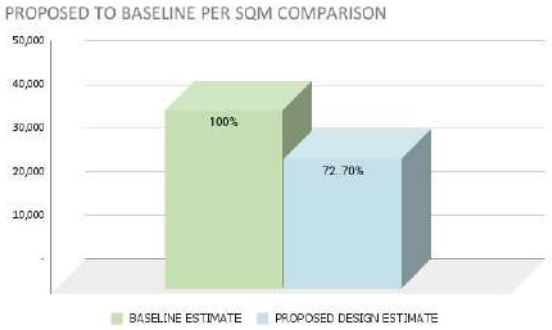



Fig.107 Cost per Sqm comparison

- Base line construction estimate is **40,997 Rupees / Sq.m**
- The proposed design estimate is **29,807 Rupees/ Sq.m**
- The proposed design cost per Sq.m is **72.70** % of the Baseline cost

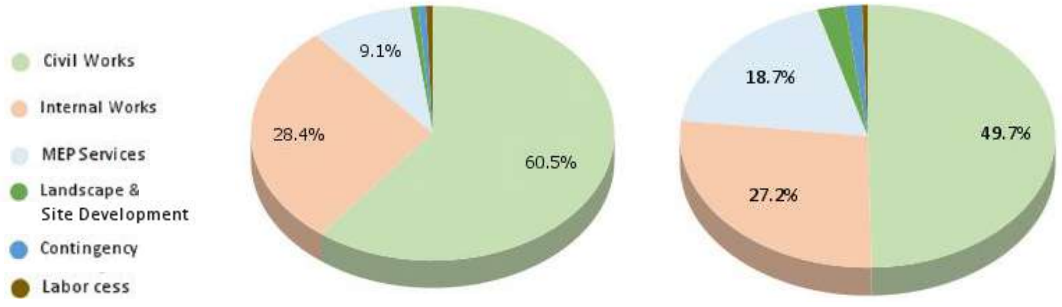
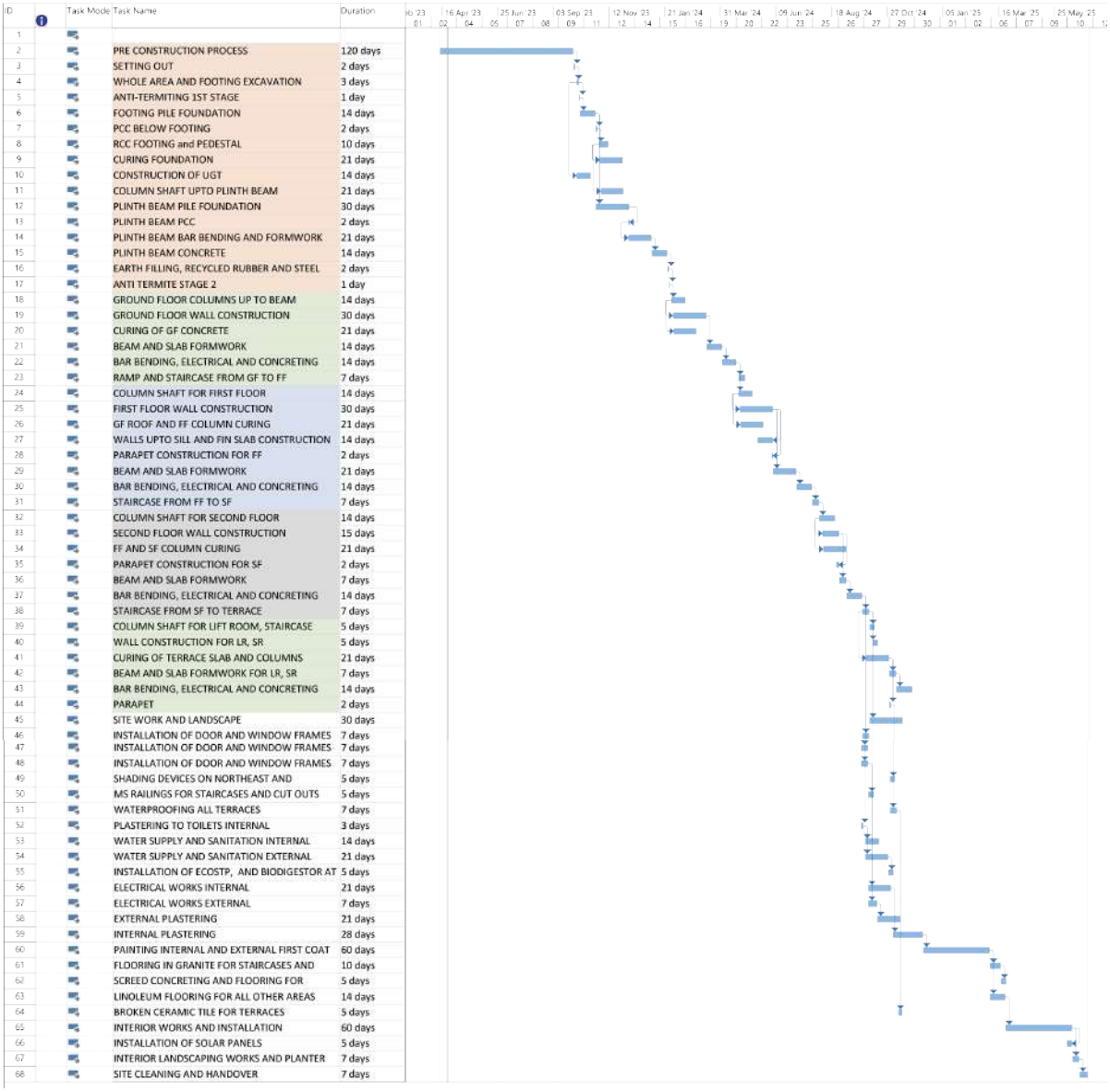



Fig. 108 Split of Construction cost comparison

# BUILDING CONSTRUCTION TIMELINE



| ID | Task Mode | Task Name | Duration |
|---|---|---|---|
| 1 | | | |
| 2 | | PRE CONSTRUCTION PROCESS | 120 days |
| 3 | | SETTING OUT | 2 days |
| 4 | | WHOLE AREA AND FOOTING EXCAVATION | 3 days |
| 5 | | ANTI-TERMITING 1ST STAGE | 1 day |
| 6 | | FOOTING PILE FOUNDATION | 14 days |
| 7 | | PCC BELOW FOOTING | 2 days |
| 8 | | RCC FOOTING and PEDESTAL | 10 days |
| 9 | | CURING FOUNDATION | 21 days |
| 10 | | CONSTRUCTION OF UGT | 14 days |
| 11 | | COLUMN SHAFT UPTO PLINTH BEAM | 21 days |
| 12 | | PLINTH BEAM PILE FOUNDATION | 30 days |
| 13 | | PLINTH BEAM PCC | 2 days |
| 14 | | PLINTH BEAM BAR BENDING AND FORMWORK | 21 days |
| 15 | | PLINTH BEAM CONCRETE | 14 days |
| 16 | | EARTH FILLING, RECYCLED RUBBER AND STEEL | 2 days |
| 17 | | ANTI TERMITE STAGE 2 | 1 day |
| 18 | | GROUND FLOOR COLUMNS UP TO BEAM | 14 days |
| 19 | | GROUND FLOOR WALL CONSTRUCTION | 30 days |
| 20 | | CURING OF GF CONCRETE | 21 days |
| 21 | | BEAM AND SLAB FORMWORK | 14 days |
| 22 | | BAR BENDING, ELECTRICAL AND CONCRETING | 14 days |
| 23 | | RAMP AND STAIRCASE FROM GF TO FF | 7 days |
| 24 | | COLUMN SHAFT FOR FIRST FLOOR | 14 days |
| 25 | | FIRST FLOOR WALL CONSTRUCTION | 30 days |
| 26 | | GF ROOF AND FF COLUMN CURING | 21 days |
| 27 | | WALLS UPTO SILL AND FIN SLAB CONSTRUCTION | 14 days |
| 28 | | PARAPET CONSTRUCTION FOR FF | 2 days |
| 29 | | BEAM AND SLAB FORMWORK | 21 days |
| 30 | | BAR BENDING, ELECTRICAL AND CONCRETING | 14 days |
| 31 | | STAIRCASE FROM FF TO SF | 7 days |
| 32 | | COLUMN SHAFT FOR SECOND FLOOR | 14 days |
| 33 | | SECOND FLOOR WALL CONSTRUCTION | 15 days |
| 34 | | FF AND SF COLUMN CURING | 21 days |
| 35 | | PARAPET CONSTRUCTION FOR SF | 2 days |
| 36 | | BEAM AND SLAB FORMWORK | 7 days |
| 37 | | BAR BENDING, ELECTRICAL AND CONCRETING | 14 days |
| 38 | | STAIRCASE FROM SF TO TERRACE | 7 days |
| 39 | | COLUMN SHAFT FOR LIFT ROOM, STAIRCASE | 5 days |
| 40 | | WALL CONSTRUCTION FOR LR, SR | 5 days |
| 41 | | CURING OF TERRACE SLAB AND COLUMNS | 21 days |
| 42 | | BEAM AND SLAB FORMWORK FOR LR, SR | 7 days |
| 43 | | BAR BENDING, ELECTRICAL AND CONCRETING | 14 days |
| 44 | | PARAPET | 2 days |
| 45 | | SITE WORK AND LANDSCAPE | 30 days |
| 46 | | INSTALLATION OF DOOR AND WINDOW FRAMES | 7 days |
| 47 | | INSTALLATION OF DOOR AND WINDOW FRAMES | 7 days |
| 48 | | INSTALLATION OF DOOR AND WINDOW FRAMES | 7 days |
| 49 | | SHADING DEVICES ON NORTHEAST AND | 5 days |
| 50 | | MS RAILINGS FOR STAIRCASES AND CUT OUTS | 5 days |
| 51 | | WATERPROOFING ALL TERRACES | 7 days |
| 52 | | PLASTERING TO TOILETS INTERNAL | 3 days |
| 53 | | WATER SUPPLY AND SANITATION INTERNAL | 14 days |
| 54 | | WATER SUPPLY AND SANITATION EXTERNAL | 21 days |
| 55 | | INSTALLATION OF ECOSTP, AND BIODIGESTOR AT | 5 days |
| 56 | | ELECTRICAL WORKS INTERNAL | 21 days |
| 57 | | ELECTRICAL WORKS EXTERNAL | 7 days |
| 58 | | EXTERNAL PLASTERING | 21 days |
| 59 | | INTERNAL PLASTERING | 28 days |
| 60 | | PAINTING INTERNAL AND EXTERNAL FIRST COAT | 60 days |
| 61 | | FLOORING IN GRANITE FOR STAIRCASES AND | 10 days |
| 62 | | SCREED CONCRETING AND FLOORING FOR | 5 days |
| 63 | | LINOLEUM FLOORING FOR ALL OTHER AREAS | 14 days |
| 64 | | BROKEN CERAMIC TILE FOR TERRACES | 5 days |
| 65 | | INTERIOR WORKS AND INSTALLATION | 60 days |
| 66 | | INSTALLATION OF SOLAR PANELS | 5 days |
| 67 | | INTERIOR LANDSCAPING WORKS AND PLANTER | 7 days |
| 68 | | SITE CLEANING AND HANDOVER | 7 days |

*Table x. Building Construction Timeline*

# BUILDING CONVERSION TIMELINE

| STEPS | VOLUNTEERS | No. of people | TYPOLOGY | TIME TAKEN PER ONE PERSON | TOTAL TIME | 100 mins | 30 mins | 36 mins |
|---|---|---|---|---|---|---|---|---|
| CLEARING RUBBLE AND CREATING SMOOTH ENTRY EXTERNAL | 10 | 0 | | 10 | 100 | | | |
| VOLUNTEER SETTING UP THE CIRCULATION SPACES INTERNALLY | 10 | 0 | | 3 | 30 | | | |
| REGISTERATION AND ALLOCATION | 4 | 530 | | 1 | 133 | | | |
| **TOTAL NO OF VOLUNTEERS** | **24** | | | | | | | |
| **STEPS** | **VOLUNTEERS** | **No. of furniture** | **TYPOLOGY** | **TIME TAKEN PER ONE PERSON** | **TOTAL TIME** | | | |
| **GROUND FLOOR** | | | | | | | | |
| INSTALLATION OF PORTABLE TOILETS | 4 | 10 | | 10 | 25 | | | |
| CONVERSION OF SEMINAR HALL | 4 | 28 | chairs to beds | 1 | 7 | | | |
| | 3 | 9 | bunk beds | 5 | 15 | | | |
| CONVERSION OF WORKSHOPS (gf) | 2 | 18 | chairs to beds | 1 | 9 | | | |
| | 4 | 12 | bunk beds | 5 | 15 | | | |
| | 4 | 24 | mattresses transfer | 5 | 30 | | | |
| CONVERSION OF EQUIPMENT ROOM (gf) | 4 | 18 | bunk beds | 5 | 23 | | | |
| **TOTAL NO OF VOLUNTEERS** | **25** | | | | | | | |
| **FIRST FLOOR** | | | | | | | | |
| CONVERSION OF CORRIDORS (first floor) | 7 | 46 | mattresses transfer | 5 | 33 | | | |
| | 4 | 23 | bunk beds | 5 | 29 | | | |
| CONVERSION OF WORKSHOPS (ff) | 2 | 18 | chairs to beds | 1 | 9 | | | |
| | 4 | 17 | bunk beds | 5 | 21 | | | |
| | 4 | 24 | mattresses transfer | 5 | 30 | | | |
| CONVERSION OF CONFERENCE ROOM (FF) | 4 | 8 | bunk beds | 5 | 10 | | | |
| CONVERSION OF SEMINAR HALL (FF) | 2 | 42 | chairs to bed | 1 | 21 | | | |
| | 5 | 36 | bunk beds | 5 | 36 | | | |
| CONVERSION OF GYM TO FIELD HOSPITAL | 4 | 18 | field hospital | 1 | 5 | | | |
| **TOTAL NO OF VOLUNTEERS** | **36** | | | | | | | |

*Table xi. Building Conversion Timeline*

- We have prepared a Construction timeline that determines when the shelter will be ready to use in case of an emergency. The sooner the shelter is constructed, the better prepared the community will be in the event of a disaster. This is done to ensure that the project stays on schedule and within budget, helps in allocating resources efficiently.
- **We want to communicate the timeline to the community, so that the residents can stay informed about the project's progress and be involved in the process.**
- The construction of the project would get **completed in 770 days** as per the above timeline.
- The Conversion Timeline is prepared to show number of volunteers needed to convert the building in the event of disaster, depending upon the criticality of the situation.
- **When the building is under conversion in the event of disaster, the initial registration of people etc can be completed under 2 hours 15 minutes. The Ground floor, given 25 volunteers can be ready for occupation in 30 minutes. Similarly, First floor can be ready in 33 minutes.**

## 8.J. VALUE PROPOSITION

### PROJECT PARTNER BENEFITS

- Climate resilient
- Earthquake resilient
- Climate Resilient

- 86,63,797 litres of rainwater harvested/annum
- 30% is consumed , rest given off to the grid

- Reduction in operation cost because of using eco-STP, rainwater harvesting, solar panels

- Passive strategies have been used reducing the EPI by 47%

- Using convertible furniture which can be replicated in other buildings

- During disaster, battery storage can sustain the building for 4 days

- Increasing the comfort of the occupants by designing shading devices such that the interior spaces are lighted up even when the lights aren't switched on

- Reduction in transportation costs by using locally available materials

Fig 109. Project partner benefits

### USER BENEFITS

- Integrating greenery in the office spaces to increase the productivity of the workers

- Privacy to the office users as they are placed on the topmost floor

- Outsiders can enter the building from the exterior itself instead of entering the building every time

Fig 110. User benefits

## MOBILE APPLICATION

The team aims to design an application that is not only focused on the particular building being designed but also try and help the general public as well. The app acts as an alert as well as an awareness app, alerting the users during times of disaster and guiding them to safer places and spreading awareness about different disasters and how to take precautions against them. At the same time, the app is working even during non-disaster times, providing activities and notifications that help raise awareness but also help keep the mind active

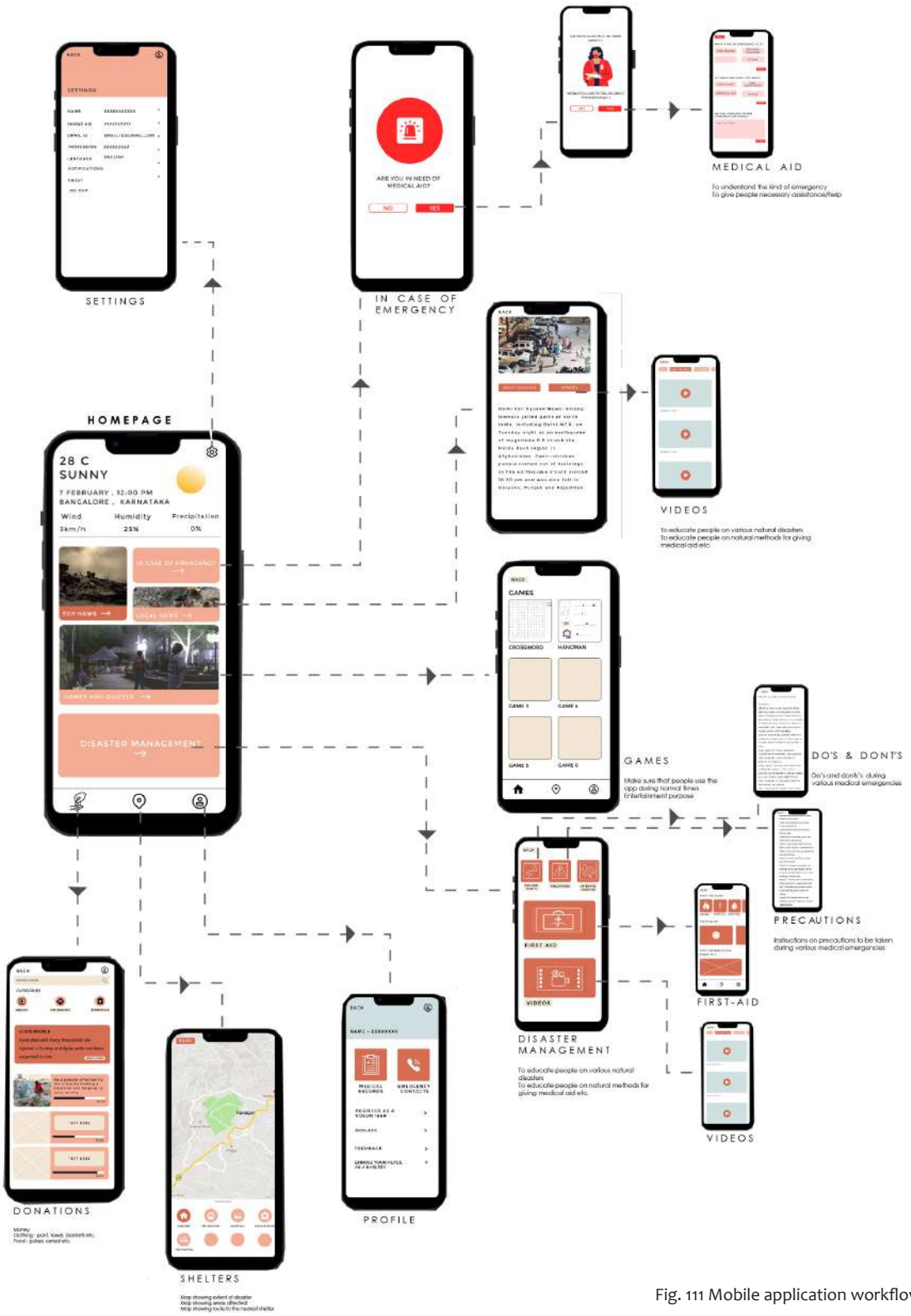



Fig. 111 Mobile application workflow


Fig. 112 Value proposition poster

# 9. APPENDIX

## 9.1 BUILDING AREA PROGRAM

| UNDER NORMAL CIRCUMSTANCES - NON DISASTER PERIOD | | UNDER EMERGENCY CIRCUMSTANCES - DISASTER PERIOD | |
|---|---|---|---|
| SPACES | AREA (sq.m) | SPACES | AREA (sq.m) |
| **BUSINESS ( OFFICE)** | **1173** | **BUSINESS ( OFFICE)** | **1173** |
| **Designations:** | | **Designations:** | |
| Deputy Secretary + P.A | 23 | Deputy Secretary + P.A | 23 |
| Under secretary + P.A | 30 | Under secretary + P.A | 30 |
| Commissioner Room +P.A + Visitors room | 80 | Commissioner Room +P.A + Visitors room | 80 |
| Joint Secretary room +P.A | 30 | Joint Secretary room +P.A | 30 |
| Director + P.A | 45 | Director + P.A | 45 |
| Minister's room + P.A | 52 | Minister's room + P.A | 52 |
| Commissioner Room +P.A | 45 | Commissioner Room +P.A | 45 |
| Open Offices | 550 | Open Offices | 550 |
| Conference Hall | 40 | Conference Hall | 40 |
| Meeting Room | 30 | Meeting Room | 30 |
| Peon Station + staff room | 25 | Peon Station + staff room | 25 |
| Department Room | 60 | Department Room | 60 |
| State Alert and Warning system | 65 | State Alert and Warning system | 65 |
| Record Room : Archives | 15 | Record Room : Archives | 15 |
| Store room | 25 | Store room | 25 |
| Control room | 8 | Control room | 8 |
| Facility Management Room | 50 | Facility Management Room | 50 |
| **EDUCATION (HEALTH TRAINING CENTRE)** | **948** | **REFUGE SHELTER** | **948** |
| Workshop spaces X2 : medical + precautionary | 170x2 | Shelter Rooms | 820 |
| Seminar Hall (Ground Floor) | 200 | | |
| Seminar halls (First Floor) | 280 | | |
| Equipment store( for disaster) : stretchers,etc + portable toilet | 65 | Equipment store( for disaster) + Bunk beds | 65 |
| Dormitory for visitors | 63 | Dormitory for visitors | 63 |
| **COMMON SPACES** | **1239** | **COMMON SPACES** | **1239** |
| Wellness centre | 40 | Wellness centre | 40 |
| Day Care centre | 28 | Shelter room | 28 |
| Gym | 140 | Gym | 140 |
| Space for SBI Bank | 100 | Space for SBI Bank | 100 |
| Food Store | 50 | Food Store | 50 |
| Food Court / dining | 140 | Food Court / dining | 140 |
| Kitchen | 50 | Kitchen | 50 |
| Utility space (washing ,etc.) | 50 | Expanded to kitchen | 50 |
| Toilets + Bath | 75x 3 | Toilets + Bath | 75x3 |
| Locker room | 16 | Lockers for valuables | 16 |
| Staircase area | (25x2)x 3 floors | Staircase area | (25x2)x 3 floors |
| Lift shaft | 3 | Lift shaft | 3 |
| Service Room | 32 | Service Room | 32 |
| Parking | 215 | Toilets | 215 |

| | | | |
|---|---|---|---|
| **HARDSCAPE AREA** | **1214** | **TERRACED AREA** | **1435** |
| Parking | 215 | First Floor terraces | 35 + 86 |
| Driveway | 660 | Second Floor terraces | 142 + 42 + 63 |
| Entance plazas | 35 + 39 | Second Floor Roof | 1067 |
| Paved Area for workshops | 265 | **LANDSCAPE AREA** | **1580** |

Table1 Building area programme

Spaces with same functionality

Spaces with changing functionality

The entire building will be non conditioned, i.e., mechanically ventilated with HLVS fans and natural ventilation will happen through passive design strategies like increased window to wall ratio and use of landscape.

## 9.2 ARCHITECTURE DRAWINGS


Figure i - Office balcony with pergola

Figure ii - Office balcony on the front facade

Figure iii - Balcony from the break room view

Figureiv - Balcony with community gardening

Figure v - Building front view elevation

## 9.4 ENGINEERING DRAWINGS

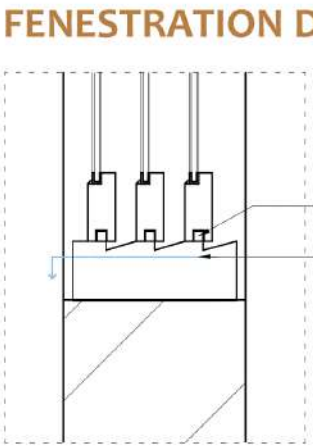



Figure vi - Weep hole detail

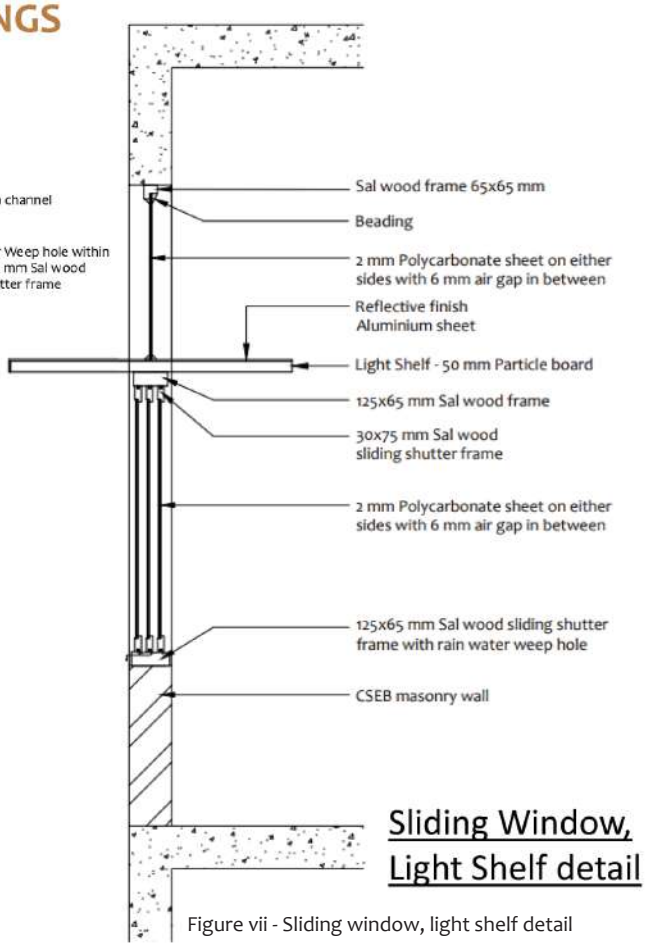



Figure vii - Sliding window, light shelf detail

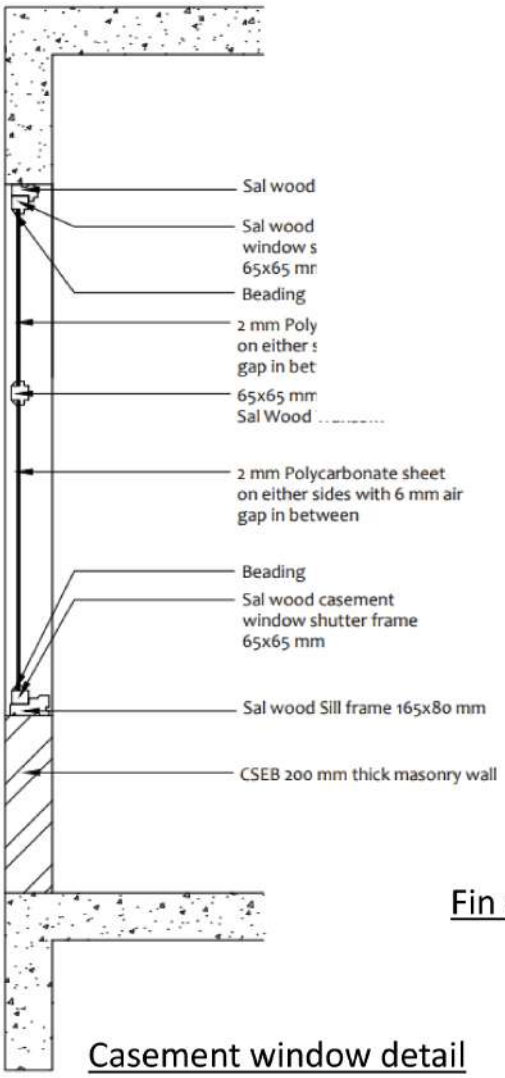



Figure viii - Casement window detail

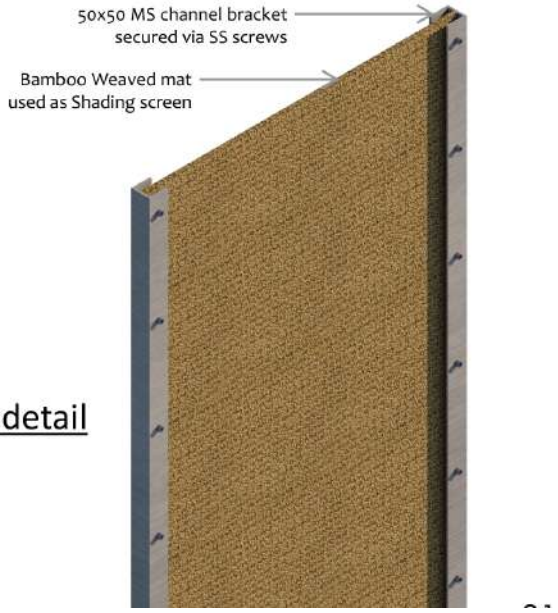
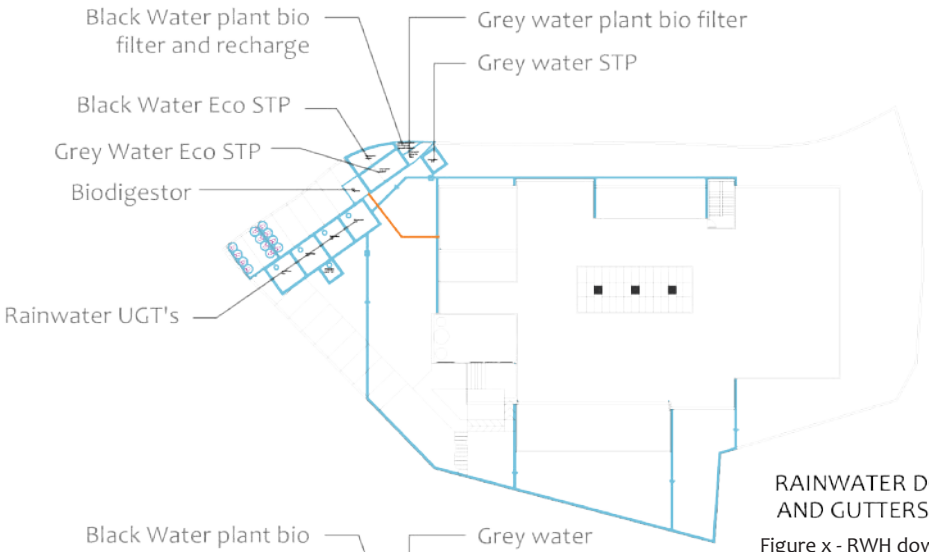


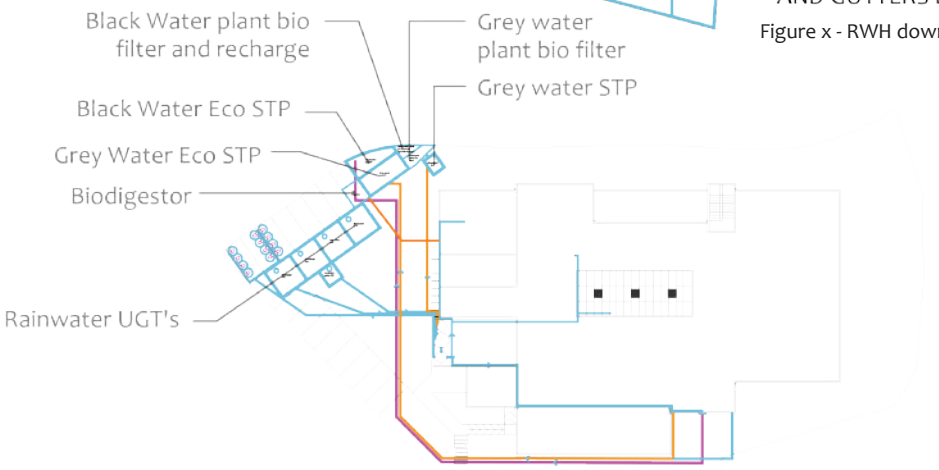

Figure ix - Fin detail (Shading device)

## PLUMBING LAYOUTS




RAINWATER DOWN-TAKE PIPES AND GUTTERS LAYOUT

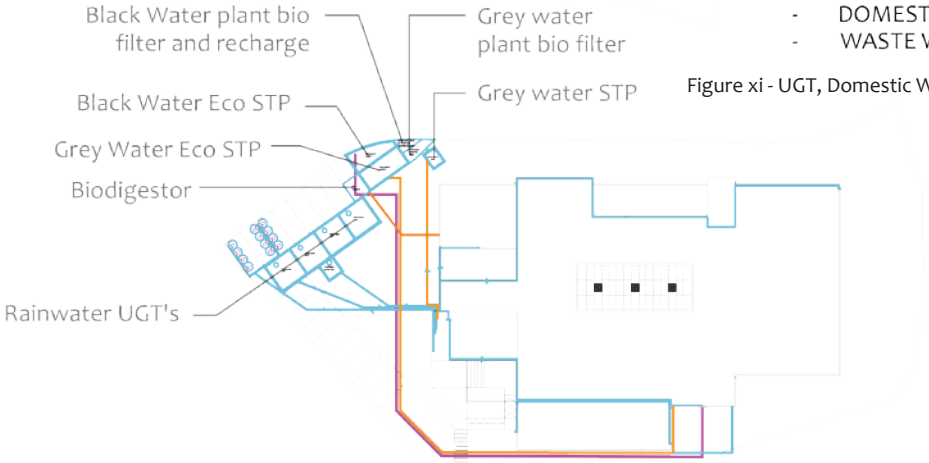
Figure x - RWH downtake pipe layout




THE LAYOUT CONTAINS:

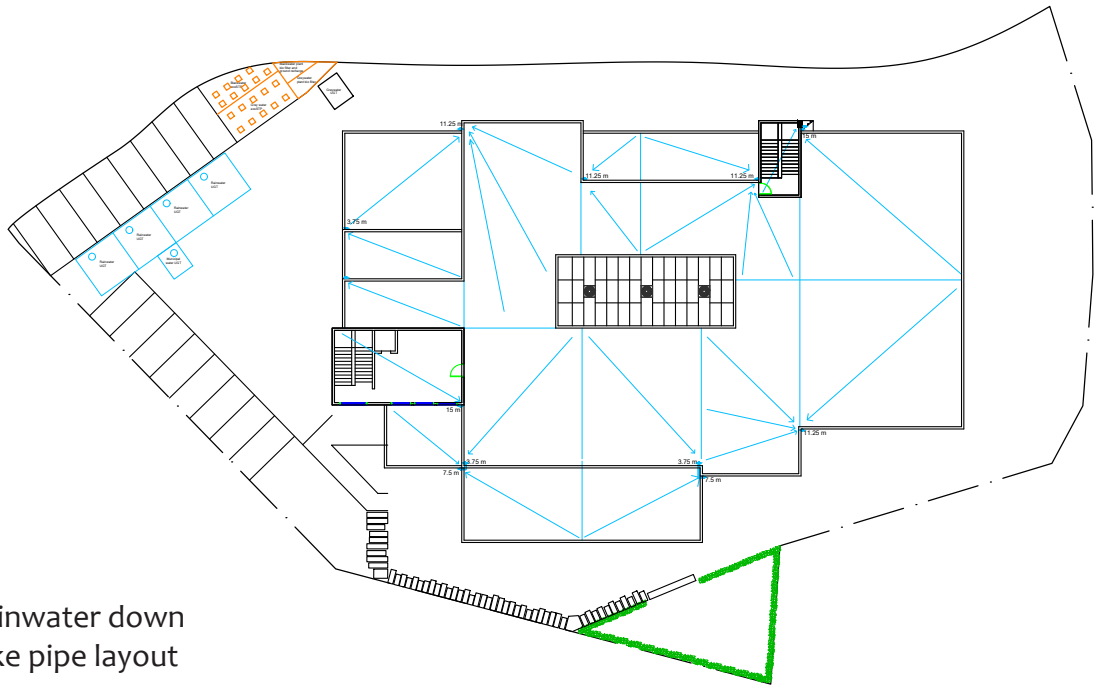
- UGT TO OHT PIPES
- DOMESTIC WATER SUPPLY PIPES
- WASTE WATER PIPES TO UGT

Figure xi - UGT, Domestic W/S, Waste water pipe layout




PIPE LAYOUT FOR LANDSCAPING

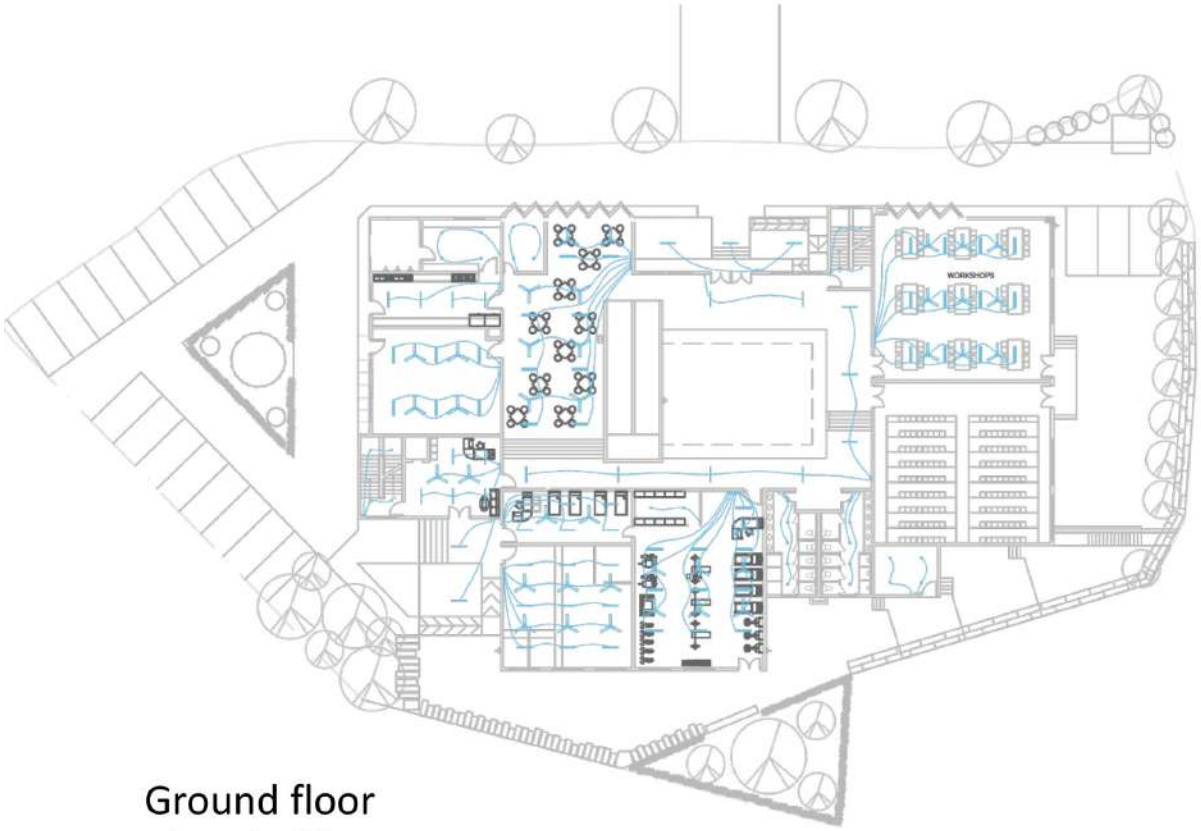
Figure xii - Pipe layout for landscaping




Rainwater down take pipe layout

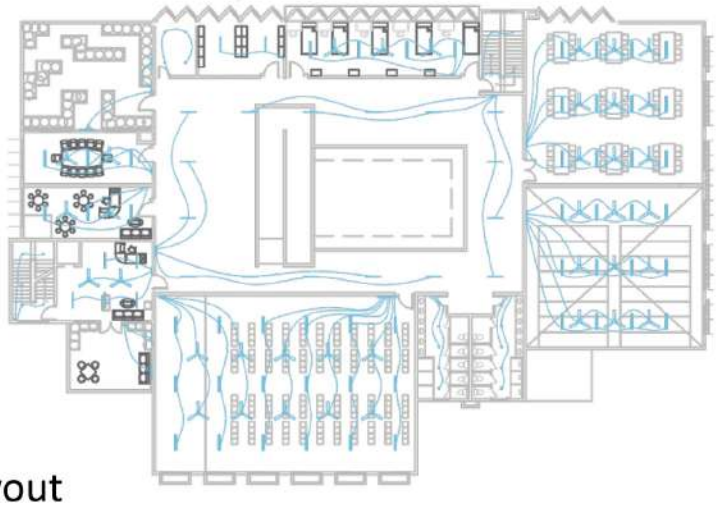
Figure xiii - Rainwater down take pipe layout

# ELECTRICAL AND SOLAR PANEL LAYOUT



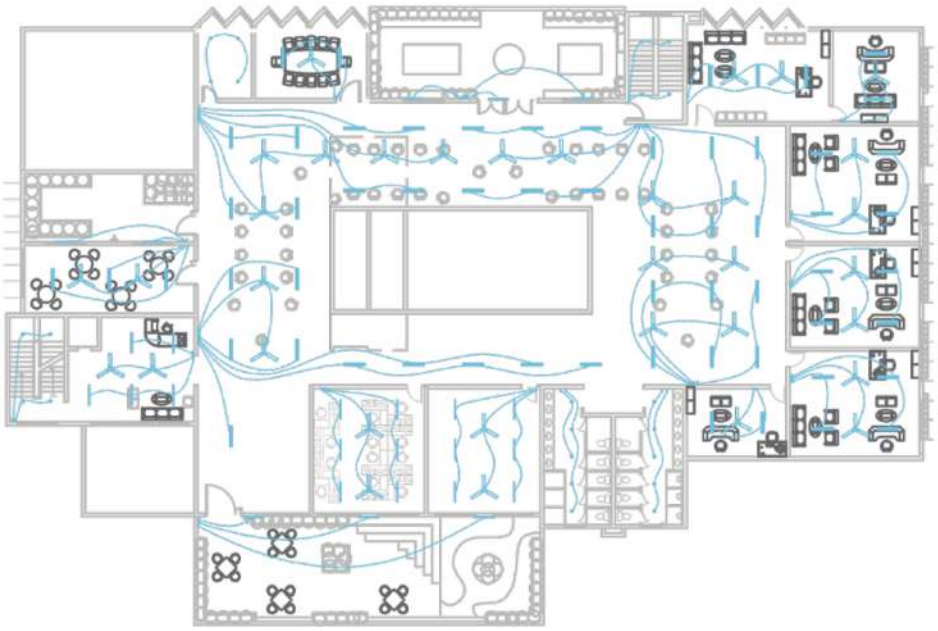

Ground floor
Electrical layout

Figure xiv - Ground floor electrical layout



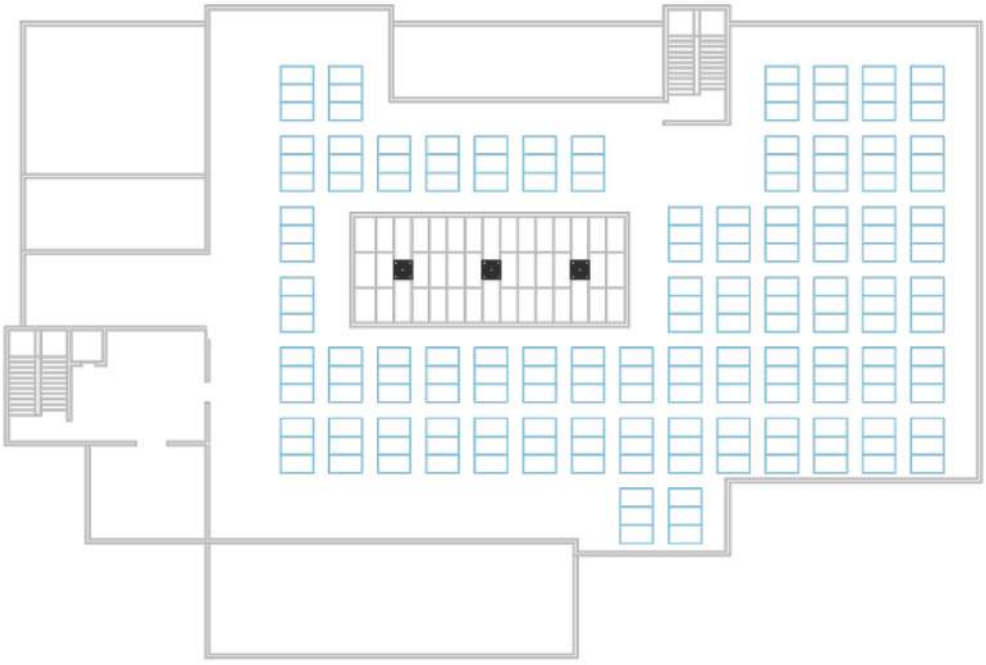
First floor
Electrical layout

Figure xv - First floor electrical layout



Second floor Electrical layout

Figure xvi - Second floor electrical layout



Terrace floor Solar panel layout

Figure xvii - Terrace floor solar panel layout

## 9.5 OUTLINE SPECIFICATION OF RELEVANT BUILDING SYSTEMS

01 **Pile foundation :** use of short piles, the piles are bored below both the plinth beam as well as to the footing

02 **Waffle slab system :** locally available wicker baskets are used as pods for the waffle

03 **Compressed Stabilised Earth Blocks :** Walls are made up of CSEB, interlocking of these blocks are done to provide more resilience against disasters, bamboo poles are also inserted at regular intervals for extra stability of the building

04 **Footing :** The refill mix for the footing is made up of excavated earth, recycled rubber pieces and steel fibres to absorb earthquake vibrations

05 **Eco STP :** one of the sustainable methods to treat wastewater. The system contains 3 RDF chambers, a plant bio filter, with zero electricity requirement

06 **Rainwater harvesting :** reliable source of water during normal times and also disaster. By using rainwater harvesting system the building is reducing its demand on the municipal water supply completely.

07 **LED light fixtures :** Led light fixtures are extremely energy efficient, and use 90% less power than the traditional light sources. This results in lower energy bills and reduced environmental impact. They have a much longer lifespan hence, reducing the operational cost of the building. Generates less heat than traditional lighting sources, thus, keeping the interiors cool.

08 **Energy Generation :** Solar panels have been implanted on the roof top of the building, gym equipment and prayer wheels are the other sources of electricity generation.

09 **Brush Less DC Fans :** BLDC fans are more efficient at moving air and can produce a higher air flow rate with less noise, resulting in better performance and comfort.

Figure xviii - Outline Specification Of Relevant Building Systems

## 9.7 ENERGY PERFORMANCE

| SPACES | AREA (sq.m) | Lpd (W/m^2) | Lighting power allowance | LPA (kWh per year) |
|---|---|---|---|---|
| BUSINESS ( OFFICE) | 1500 | | | |
| | | | | |
| State Alert and Warning system | 65 | 10 | 650 | 1627.6 |
| Record Room - archives | 15 | 10 | 150 | 375.6 |
| Control room | 8 | 10 | 80 | 200.32 |
| Facility Management Room | 50 | 10 | 500 | 1252 |
| Open Offices | 550 | 10 | 5500 | 13772 |
| Store room | 25 | 6.8 | 170 | 425.68 |
| Conference Hall | 40 | 11.5 | 460 | 1151.84 |
| Meeting Room | 30 | 11.5 | 345 | 863.88 |
| Peon Station + staff room | 25 | 10 | 250 | 626 |
| Department Room | 60 | 10 | 600 | 1502.4 |
| | | | | |
| Designations: | | | | |
| Deputy Secretary + P.A | 23 | 10 | 230 | 575.92 |
| Under secretary + P.A | 30 | 10 | 300 | 751.2 |
| Commissioner Room +P.A + Visitors room | 80 | 10 | 800 | 2003.2 |
| Joint Secretary room +P.A | 30 | 10 | 300 | 751.2 |
| Director + P.A | 45 | 10 | 450 | 1126.8 |
| Minister's room + P.A | 52 | 10 | 520 | 1302.08 |
| Commissioner Room +P.A | 45 | 10 | 450 | 1126.8 |
| | 1173 | | | |
| EDUCATION (HEALTH TRAINING CENTRE) | 2000 | | | |
| Workshop spaces X2 : medical + precautionary | 400 | 17.1 | 6840 | 17127.36 |
| Seminar Hall (Ground Floor) | 200 | 11.5 | 2300 | 5759.2 |
| Seminar halls (First Floor) | 280 | 11.5 | 3220 | 8062.88 |
| Equipment store( for disaster) : stretchers,etc + portable toilet | 65 | 6.8 | 442 | 1106.768 |
| | 945 | | | |
| COMMON SPACES | 1191 | | | |
| Wellness centre | 40 | 9.4 | 376 | 941.504 |
| Day care center | 28 | 10 | 280 | 701.12 |
| Gym | 140 | 13.7 | 1918 | 4802.672 |
| Food Store | 50 | 6.8 | 340 | 851.36 |
| Food Court / dining | 140 | 14.1 | 1974 | 4942.896 |
| Kitchen | 50 | 12.1 | 605 | 1514.92 |
| Utility space (washing ,etc.) | 50 | 6.8 | 340 | 851.36 |
| SBI bank | 100 | 12.6 | 1260 | 3155.04 |
| Toilet + bath | 225 | 7.7 | 1732.5 | 4338.18 |
| Lift shaft | 3 | 5.5 | 16.5 | 41.316 |
| Staircase lobby | 150 | 5.5 | 825 | 2065.8 |
| Parking | 215 | 2.2 | 473 | 1184.392 |
| | | | | |
| Total | 3309 | | 22469 | 86881.288 |

Table 2 Lighting calculation - Base case

| SPACE | | AREA (SQ.M) | LUX LEVEL | FIXTURE TYPE | NUMBER OF FIXTURES | TOTAL WATTAGE |
|---|---|---|---|---|---|---|
| **NORMAL** | **DISASTER TIME** | | | | | |
| **GROUND FLOOR** | | | | | | |
| Workshop | Shelter room | 180 | 300 | LED Battens | 24 | 864 |
| Seminar hall | Shelter room | 180 | 300 | LED Battens | 24 | 864 |
| Toilet storage | Toilet storage | 20 | 100 | LED Downlight | 4 | 40 |
| Toilets | Toilets | 64 | 100 | LED Downlight | 10 | 100 |
| Gym | Field hospital extention | 144 | 300 | LED Battens | 20 | 720 |
| SBI bank | SBI bank | 100 | 300 | LED Battens | 9 | 324 |
| Wellness center | Field hospital | 42 | 300 | LED Battens | 6 | 216 |
| Reception | Reception | 44 | 300 | LED Battens | 5 | 180 |
| Staircase 1 | Staircase 1 | 21 | 100 | LED Downlight | 4 | 40 |
| Equipment storage | Shelter room | 86 | 300 | LED Battens | 12 | 432 |
| Kitchen | Kitchen | 42 | 200 | LED Battens | 4 | 144 |
| Food storage | Food storage | 26 | 100 | LED Downlight | 4 | 40 |
| Utility | Utility | 16 | 100 | LED Downlight | 4 | 40 |
| Electrical room | Electrical room | 16 | 100 | LED Downlight | 4 | 40 |
| Food court | Food court | 135 | 300 | LED Battens | 16 | 576 |
| Staircase 2 | Staircase 2 | 21 | 100 | LED Downlight | 4 | 40 |
| Corridor | Corridor | 195 | 100 | LED Battens | 9 | 324 |
| Office entrance | Office entrance | 34 | 100 | LED Battens | 2 | 72 |
| Main entrance | Main entrance | 66 | 100 | LED Battens | 3 | 108 |
| **FIRST FLOOR** | | | | | | |
| Workshop | Shelter room | 180 | 300 | LED Battens | 24 | 864 |
| (Seminar hall) | (Shelter room) | 0 | | | | |
| Toilets | Toilets | 64 | 100 | LED Downlight | 10 | 100 |
| Seminar hall 2 | Shelter room | 288 | 300 | LED Battens | 36 | 1296 |
| Reception | Reception | 44 | 300 | LED Battens | 5 | 180 |
| Staircase 1 | Staircase 1 | 21 | 100 | LED Downlight | 4 | 40 |
| Daycare | Daycare | 42 | 300 | LED Battens | 6 | 216 |
| Conference room | Shelter room | 42 | 300 | LED Battens | 6 | 216 |
| Electrical room | Electrical room | 16 | 100 | LED Downlight | 4 | 40 |
| Archives | Archives | 34 | 200 | LED Battens | 2 | 72 |
| Dormitory | Dormitory | 64 | 300 | LED Battens | 8 | 288 |
| Staircase 2 | Staircase 2 | 21 | 100 | LED Downlight | 4 | 40 |
| Corridor | Corridor | 390 | 100 | LED Battens | 16 | 576 |
| Terrace 1 | Terrace 1 | 34 | | | 2 | 72 |
| Terrace 2 | Terrace 2 | 66 | | | 2 | 72 |
| **SECOND FLOOR** | | | | | | |
| Commissioner | Commissioner | 78 | 300 | LED Battens | 10 | 240 |
| Minister | Minister | 56 | 300 | LED Battens | 8 | 192 |
| Under Secretary | Under Secretary | 48 | 300 | LED Battens | 8 | 192 |
| Deputy Secretary | Deputy Secretary | 50 | 300 | LED Battens | 8 | 192 |
| Joint Secretary | Joint Secretary | 26 | 300 | LED Battens | 4 | 96 |
| Toilets | Toilets | 64 | 100 | LED Downlight | 10 | 100 |
| State alert room | State alert room | 48 | 300 | LED Battens | 6 | 144 |
| Department room | Department room | 48 | 300 | LED Battens | 6 | 144 |
| Reception | Reception | 44 | 300 | LED Battens | 5 | 120 |
| Staircase 1 | Staircase 1 | 21 | 100 | LED Downlight | 4 | 40 |
| Break room | Break room | 42 | 300 | LED Battens | 6 | 144 |
| Electrical room | Electrical room | 16 | 100 | LED Downlight | 4 | 40 |
| Meeting room | Meeting room | 34 | 300 | LED Battens | 4 | 96 |
| Staircase 2 | Staircase 2 | 21 | 100 | LED Downlight | 4 | 40 |
| Open office | Open office | 540 | 300 | LED Battens | 70 | 1680 |
| Terrace 3 | Terrace 3 | 142 | | | 3 | 108 |
| Terrace 4 | Terrace 4 | 42 | | | 2 | 72 |
| Terrace 5 | Terrace 5 | 64 | | | 3 | 108 |

Table 3 Lighting calculation - Proposed case

| EQUIPMENT | QUANTITY | WATTAGE | HOURS | NO OF DAYS | TOTAL (kWh) |
|---|---|---|---|---|---|
| Laptop | 120 | 50 | 8 | 313 | 15024 |
| Projector | 6 | 150 | 4 | 313 | 1126.8 |
| Telephone | 20 | 5 | 8 | 313 | 250.4 |
| Refrigirator | 5 | 300 | 24 | 365 | 13140 |
| Printer | 8 | 300 | 2 | 313 | 1502.4 |
| Microwave | 4 | 800 | 2 | 313 | 2003.2 |
| Water purifier | 7 | 70 | 24 | 313 | 3680.88 |
| Water pumps | 2 | 1500 | 0.5 | 365 | 547.5 |
| Water pumps | 1 | 750 | 0.5 | 365 | 136.875 |
| Lift | 1 | 1000 | 8 | 313 | 2504 |
| 6A sockets | 50 | 100 | 8 | 313 | 12520 |
| 16A sockets | 20 | 1000 | 2 | 313 | 12520 |
| | | | | | **64956.055** |
| **VENTILATION** | | | | | |
| Ceiling fans | 108 | 28 | 8 | 313 | 7572.096 |
| Exhaust fan | 7 | 16 | 4 | 313 | 140.224 |
| | | | | | **7712.32** |
| **LIGHTING** | | | | | |
| LED Battens | 384 | 36 | 8 | 313 | 34615.296 |
| LED Downlights | 78 | 10 | 8 | 313 | 1953.12 |
| External lights | 12 | 24 | 8 | 313 | 721.152 |
| | | | | | **37289.568** |
| | | | **SDA = 50%** | **(50% reduction)** | **18644.784** |

Table 4 Load calculation - Normal scenario

| EQUIPMENT | QUANTITY | WATTAGE | HOURS | NO OF DAYS | TOTAL (kWh) |
|---|---|---|---|---|---|
| Laptop | 120 | 50 | 16 | 1 | 96 |
| Projector | 2 | 150 | 1 | 1 | 0.3 |
| Telephone | 10 | 5 | 8 | 1 | 0.4 |
| Refrigirator | 1 | 300 | 24 | 1 | 7.2 |
| Printer | 2 | 300 | 2 | 1 | 1.2 |
| Microwave | 1 | 1 | 1 | 1 | 0.001 |
| Water purifier | 7 | 70 | 24 | 1 | 11.76 |
| Water pumps | 2 | 1500 | 0.5 | 1 | 1.5 |
| Water pumps | 1 | 750 | 0.5 | 1 | 0.375 |
| Lift | 1 | 1 | 1 | 1 | 0.001 |
| 6A sockets | 50 | 100 | 16 | 1 | 80 |
| 16A sockets | 10 | 1000 | 1 | 1 | 10 |
| | | | | | **208.737** |
| **VENTILATION** | | | | | |
| Ceiling fans | 54 | 28 | 12 | 1 | 18.144 |
| Exhaust fan | 7 | 16 | 4 | 1 | 0.448 |
| | | | | | **18.592** |
| **LIGHTING** | | | | | |
| LED Battens office | 54 | 36 | 12 | 1 | 23.328 |
| LED Battens other | 40 | 36 | 8 | 1 | 11.52 |
| LED Downlights | 39 | 10 | 16 | 1 | 6.24 |
| | | | | | **41.088** |

Table 4 Load calculation - Disaster scenario

| EQUIPMENT | QUANTITY | WATTAGE | HOURS | DAYS | ENERGY PRODUCED ANNUALLY (kWh) |
|---|---|---|---|---|---|
| Treadmill | 4 | 100 | 5 | 365 | 730 |
| Training bench | 3 | 100 | 5 | 365 | 547.5 |
| Elliptical | 3 | 100 | 5 | 365 | 547.5 |
| Stationary bike | 5 | 100 | 5 | 365 | 912.5 |
| Chest press machine | 1 | 68 | 5 | 365 | 124.1 |
| Arm curler machine | 2 | 50 | 5 | 365 | 182.5 |
| | | | | **TOTAL=** | **2861.6** |

Table 5 Energy generation using gym equipment

| | Number of prayer wheels | Energy generated (W) | Energy generated in a year (kWh) |
|---|---|---|---|
| First floor atrium | 52 | 1.16 | 22.0168 |
| Second floor atrium | 66 | 1.16 | 27.9444 |
| | | | **49.9612** |

Table 6 Power of Prayer - Energy generation from Buddhist prayer wheels

(Assumption – The prayer wheel are rotated for 30 minutes everyday)

## Natural ventilation calculation :

**Algorithm used as per NBC Part 8, Natural ventilation (5.6.1.1)**
**Q = KAV**

**Example – Workshop**
K = Coefficient of effectiveness = 0.3

V = Wind speed, in m/h 4.5 km/h = 4500 m/h

A = 2 two track sliding Windows (3.6m x 1.4m), 2 three track sliding windows (2.4m x 1.4m)
A = (2 x 3.6 x 1.4 x 0.5) + (2 x 2.4 x 1.4 x 0.3)
A = 5.04 + 2.016
A = 7.056 sq.m

Q = 0.3 x 7.056 x 4500
Q = 9525.6 cum/h

Volume of room = 720
(Floor area = 200 sq.m, Height = 3.6 m)

ACH achieved = 9525.6/720 = **13.23**

## 9.6 ENERGY SIMULATION INPUTS

| Input Parameters | Units | Proposed Design values | |
|---|---|---|---|
| General | | | |
| Building area | m² | 4240 | |
| Conditioned Area | m² | - | |
| Electricity Rate | INR/kWh | 7 | |
| Natural Gas Rate | INR/GJ | | |
| Building Occupancy Hours | | Normal time - 9:00 am to 5:00 pm , During disaster - 24 hours | |
| Average Occupant Density | m² / person | | |
| | | | |
| Internal Loads | | | |
| Interior Average Lighting Power Density | W/m² | 4.4 | |
| List of Lighting Controls | | | |
| Average Equipment Power Density | W/m² | 17.1 | |
| Minimum OA Ventilation (Building Average) | l/sec.m² | | |
| | | | |
| Envelope | | | |
| Roof Assembly U value | W/m².K | 0.88 | |
| Roof Assembly SRI | | | |
| Average Wall Assembly U value | W/m².K | 0.31 | |
| Window to Wall Area Ratio (WWR) | % | | |
| Windows U value | W/m².K | 3.6 | |
| Windows SHGC | | | |
| Windows VLT | % | | |
| Infiltration rate | ac/h | | |
| Describe Exterior Shading Devices | | A sawtooth shaped wall for the Northwest façade to let in diffused north light and block west sun, Vertival fins on south east and northeast facades, Windows with light shelves on south west | |
| | | | |
| HVAC System | | Not Applicable | |
| | | | |
| Service Hot Water | | | |
| SHW Type and Description | | | |
| | | | |
| Output Parameters | Units | Proposed Design Values | |
| Proposed EUI (Total) | kWh/m²/ yr | 215 | |
| EUI Breakdown by End Use | | | |
| Heating | kWh/m²/ yr | - | |
| Cooling | kWh/m²/ yr | - | |
| Fans | kWh/m²/ yr | 1.8 | |
| Pumps | kWh/m²/ yr | 0.2 | |
| Heat rejection | kWh/m²/ yr | - | |
| Service Hot Water | kWh/m²/ yr | - | |
| Lighting | kWh/m²/ yr | 4.3 | |
| Equipment | kWh/m²/ yr | 15.2 | |
| Total Envelope Heat Gain (Peak) | W/m² | | |
| Cooling Load of Conditioned Area | SF/Tr | - | |
| Building Electric (Peak) | W/m² | | |
| Annual Operating Energy Cost | INR/m² | | |
| Annual Unmet Hours | | 30 | |
| Cooling Capacity | | - | |
| Annual Hours of Comfort without Air Conditioning | | 8730 | |
| Monthly Energy Performance | | Generation | Consumption |
| January | kWh | 8934 | 6763 |
| February | kWh | 8439 | 7124 |
| March | kWh | 9156 | 7564 |
| April | kWh | 7886 | 7896 |
| May | kWh | 7783 | 8013 |
| June | kWh | 6353 | 8178 |
| July | kWh | 6644 | 8493 |
| August | kWh | 7884 | 8145 |
| September | kWh | 6660 | 8053 |
| October | kWh | 9990 | 7506 |
| November | kWh | 9245 | 6872 |
| December | kWh | 7654 | 6708 |
| | | 96628 | 91315 |

Table 7 - Input parameters

## 9.7 WATER PERFORMANCE

Table 8 - Base Case per capita consumption

| | Function | Per Capita daily consumption | Number of occupants | Daily consumption (Litres) | Total daily consumption (Litres) |
|---|---|---|---|---|---|
| Non - disaster times | Office and Training center | 45 | 320 | 14400 | 14400 |
| Disaster times | Office | 45 | 72 | 3240 | 44640 |
| | Community resilience shelter | 90 | 460 | 41400 | |

Table 9 - Sources of water

| Months | Rainfall (mm) | Effective rain (mm) | Harvested rainwater(lpm) | Generated black water(lpm) | Generated Grey water(lpm) | Filtered grey water(lpm) | Municipal water(lpm) |
|---|---|---|---|---|---|---|---|
| July | 969 | 964 | 26,28,153 | 69440 | 138756 | 104067 | |
| Aug | 662 | 657 | 17,91,179 | 69440 | 138756 | 104067 | |
| Sep | 418 | 413 | 11,25,962 | 67200 | 134280 | 100710 | |
| Oct | 163 | 158 | 4,30,755 | 69440 | 138756 | 104067 | |
| Nov | 22 | 17 | 46,347 | 67200 | 134280 | 100710 | 211200 |
| Dec | 20 | 15 | 40,895 | 69440 | 138756 | 104067 | 218240 |
| Jan | 36 | 31 | 84,515 | 69440 | 138756 | 104067 | 218240 |
| Feb | 64 | 59 | 1,60,852 | 62720 | 125328 | 93996 | 198880 |
| Mar | 104 | 99 | 2,69,904 | 69440 | 138756 | 104067 | |
| Apr | 195 | 190 | 5,17,997 | 67200 | 134280 | 100710 | |
| May | 340 | 335 | 9,13,311 | 69440 | 138756 | 104067 | |
| June | 669 | 664 | 18,10,263 | 67200 | 134280 | 100710 | |
| Total | | | 98,20,133 | | | 1225305 | 8,46,560 |

Table 10 - Non disaster times - water consumption

| BASE CASE | | | PROPOSED CASE | |
|---|---|---|---|---|
| Quantity in lts for 320 people | Quantity in lts/person | Occupant's Activity | Quantity in lts/person | Quantity in lts for 320 people |
| 1600 | 5 | Handwash | 1.5 | 480 |
| 2560 | 8 | Drinking | 8 | 2560 |
| 2560 | 8 | Pantry | 6 | 1920 |
| 3648 | 3.8 | Urinal | 0 | 0 |
| 1920 | 6 | WC flushing | 4 | 1280 |
| 832 | 2 | Cleaning | 2 | 640 |
| 1280 | 4 | Others | 0 | 0 |
| Total = 14400LPD | | | | Total = 7076LPD |

Table 11 - Base case - total domestic water demand

| Filtered grey water | Irrigation demand | Month | Days in month | Harvested rainwater (l) | Total domestic water demand (l) |
|---|---|---|---|---|---|
| 1,16,064.00 | 4,228.96 | Jul | 31 | 2,628,153.20 | 4,46,400.00 |
| 1,16,064.00 | 4,228.96 | Aug | 31 | 1,791,179.10 | 4,46,400.00 |
| 1,12,320.00 | 4,092.55 | Sep | 30 | 1,125,961.90 | 4,32,000.00 |
| 1,16,064.00 | 10,572.41 | Oct | 31 | 430,755.40 | 4,46,400.00 |
| 1,12,320.00 | 10,231.37 | Nov | 30 | 46,347.10 | 4,32,000.00 |
| 1,16,064.00 | 10,572.41 | Dec | 31 | 40,894.50 | 4,46,400.00 |
| 1,16,064.00 | 21,144.82 | Jan | 31 | 84,515.30 | 4,46,400.00 |
| 1,04,832.00 | 19,098.55 | Feb | 28 | 160,851.70 | 4,03,200.00 |
| 1,16,064.00 | 21,144.82 | Mar | 31 | 269,903.70 | 4,46,400.00 |
| 1,12,320.00 | 20,462.73 | Apr | 30 | 517,997.00 | 4,32,000.00 |
| 1,16,064.00 | 10,572.41 | May | 31 | 913,310.50 | 4,46,400.00 |
| 1,12,320.00 | 10,231.37 | Jun | 30 | 1,810,263.20 | 4,32,000.00 |

Table 12 - Proposed case - total domestic water demand

| Filtered grey water | Irrigation demand | Month | Days in month | Harvested rainwater (l) | Total domestic water demand (l) |
|---|---|---|---|---|---|
| 1,04,067.00 | 4,228.96 | Jul | 31 | 2,628,153.20 | 2,18,240.00 |
| 1,04,067.00 | 4,228.96 | Aug | 31 | 1,791,179.10 | 2,18,240.00 |
| 1,00,710.00 | 4,092.55 | Sep | 30 | 1,125,961.90 | 2,11,200.00 |
| 1,04,067.00 | 10,572.41 | Oct | 31 | 430,755.40 | 2,18,240.00 |
| 1,00,710.00 | 10,231.37 | Nov | 30 | 46,347.10 | 2,11,200.00 |
| 1,04,067.00 | 10,572.41 | Dec | 31 | 40,894.50 | 2,18,240.00 |
| 1,04,067.00 | 21,144.82 | Jan | 31 | 84,515.30 | 2,18,240.00 |
| 93,996.00 | 19,098.55 | Feb | 28 | 160,851.70 | 1,97,120.00 |
| 1,04,067.00 | 21,144.82 | Mar | 31 | 269,903.70 | 2,18,240.00 |
| 1,00,710.00 | 20,462.73 | Apr | 30 | 517,997.00 | 2,11,200.00 |
| 1,04,067.00 | 10,572.41 | May | 31 | 913,310.50 | 2,18,240.00 |
| 1,00,710.00 | 10,231.37 | Jun | 30 | 1,810,263.20 | 2,11,200.00 |

Table 13 - Disaster times - water consumption

| BASE CASE | | | PROPOSED CASE | |
|---|---|---|---|---|
| Quantity in lts for 460 people | Quantity in lts/person | Occupant's Activity | Quantity in lts/person | Quantity in lts for 460 people |
| 11500 | 25 | Bathing | 25 | 11500 |
| 6440 | 14 | Washing | 14 | 6440 |
| 2300 | 5 | Drinking | 5 | 2300 |
| 2300 | 5 | Cooking | 5 | 2300 |
| 4244 | 3.8 | Urinal | 0 | 0 |
| 2760 | 6 | WC flushing | 4 | 1840 |
| 4600 | 10 | Washing utensils | 10 | 4600 |
| 4600 | 10 | Cleaning | 10 | 4600 |
| Total = 39800LPD | | | | Total = 33,280LPD |

During a disaster

- Only 14 lts per person is considered for laundry since only clothes like bedsheets, pillowcases would be washed in emergency times
- Similarly only 25lts is provided for bathing

Table 14 - Disaster times - water consumption - office

| BASE CASE | | | PROPOSED CASE | |
|---|---|---|---|---|
| Quantity in lts for 72 people | Quantity in lts/person | Occupant's Activity | Quantity in lts/person | Quantity in lts for 72 people |
| 360 | 5 | Handwash | 1.5 | 108 |
| 576 | 8 | Drinking | 5 | 360 |
| 576 | 8 | Pantry | 5 | 360 |
| 820.8 | 3.8 | Urinal | 0 | 0 |
| 432 | 6 | WC flushing | 4 | 288 |
| | 2 | Cleaning | 2 | 144 |
| Total = 2910LPD | | | | Total = 1260LPD |

Table 15 - Base case vs Proposed case

| Total domestic water demand (l) | Month | Days in month | Harvested rainwater (l) | Total domestic water demand (l) |
|---|---|---|---|---|
| 13,83,840.00 | Jul | 31 | 23,18,684.14 | 10,45,072 |
| 13,83,840.00 | Aug | 31 | 15,80,265.02 | 10,45,072 |
| 13,39,200.00 | Sep | 30 | 9,93,378.16 | 10,11,360 |
| 13,83,840.00 | Oct | 31 | 3,80,033.29 | 10,45,072 |
| 13,39,200.00 | Nov | 30 | 40,889.66 | 10,11,360 |
| 13,83,840.00 | Dec | 31 | 36,079.11 | 10,45,072 |
| 13,83,840.00 | Jan | 31 | 74,563.49 | 10,45,072 |
| 12,61,080.00 | Feb | 28 | 1,41,911.17 | 9,43,936 |
| 13,83,840.00 | Mar | 31 | 2,38,122.13 | 10,45,072 |
| 13,39,200.00 | Apr | 30 | 4,57,002.06 | 10,11,360 |
| 13,83,840.00 | May | 31 | 8,05,766.79 | 10,45,072 |
| 13,39,200.00 | Jun | 30 | 15,97,101.94 | 10,11,360 |

Table 16 - Irrigation demand

| Month | Days in month | Irrigation seasonal factor (%) | Irrigation demand |
|---|---|---|---|
| Jul | 31 | 20% | 16653 |
| Aug | 31 | 20% | 16653 |
| Sep | 30 | 20% | 16116 |
| Oct | 31 | 50% | 41633 |
| Nov | 30 | 50% | 40290 |
| Dec | 31 | 50% | 41633 |
| Jan | 31 | 100% | 83266 |
| Feb | 28 | 100% | 75208 |
| Mar | 31 | 100% | 83266 |
| Apr | 30 | 100% | 80580 |
| May | 31 | 50% | 41633 |
| Jun | 30 | 50% | 40290 |
| | | Total irrigation demand (l) = | 577221 |

| Water use | Area($m^2$) | Litres/day |
|---|---|---|
| Irrigation (max) : {$m^2$ x l/$m^2$} | 1580 | 1.7 |

| Type of fixture |  |  |  |  |  |
|---|---|---|---|---|---|
| Specifications | Jaquar Sink Cock with Regular Swinging Spout | Jaquar sensor faucet | Jaquar Allied Hand Shower | Hindware ultra low flush toilet | Parryware Astute Waterless Urinal |
| Flow rate (lpm/lpf) | 6 | 6 | 4 | 4 | 0 |
| Cost (INR) | 2000 | 4600 | 1587 | 13000 | 11830 |

**TANK SIZES**

**UNDER GROUND WATER STORAGE**
Tank 1 - Rainwater tank
Capacity = 1,50,000 lakh liters =150 m3
Size – 25 x 3 x 2 m(L x B x H)

Tank 2 – municipal water tank
Capacity = 7500 liters =7.5 m3
Size – 2.5 x 2 x 1.5 m(L x B x H)

Tank 3 – filtered grey water tank
Capacity - 3000 lts = 3 m3
Size – 2.1 x 1.8 x 1.2 m(L x B x H)

**OVERHEAD WATER STORAGE**
Tank 1 - Domestic water tank
Capacity - 5000 * 1 day storage = 5m3
Size –1.8 x 2.2m (Dia x H)

Tank 2 - Municipal water tank
Capacity - 3000 * 1 day storage = 3m3
Size –1.5 x 1.72m (Dia x H)

Tank 3 – recycled grey water tank
Capacity - 3000 * 1 day storage = 3m3
Size –1.5 x 1.72m (Dia x H)

**SEWAGE TREATMENT PLANT**
For a 7.7 kld
Stage 1 – 20 sqm
Stage 4 – 9 sqm

For separating grey and black water 10% additional space
Stage 1 – 22 sqm
Stage 4 – 10 sqm

**PIPE RATES**
RW down take pipes
Finolex PVC 160mm dia, 12m long pipes – 150 rs/m

Soil pipe
Finolex PVC 110 dia, 6m long pipes – 185 rs/m

Grey water pipe
Finolex PVC 75 dia, 6m long pipes – 130 rs/m

Water inlet pipe
Astral CPVC 50 dia, 5m long pipes – 2380 rs/m

**RO WATER PURIFIER** – 17000 rs

2 HP Texmo Submersible Pump

| Number Of Stages | Multi Stage Pump |
|---|---|
| Motor Horsepower | 2 HP |
| Brand | Texmo, Deccan Ekki , Kirloskar, Sharp tech, Kissan |
| Usage/Application | water |
| Type | Borewell |

Texmo SHR 4 (1 HP) Domestic Water pump

| Brand Name : | Texmo |
|---|---|
| Phase : | Single Phase |
| Model No : | SHR 4 |
| Type of Product : | Self Priming Monoblock Pump |
| Voltage : | 180-230 V |
| Frequency : | 50 Hz |

# 9.8 SUMMARY OF COST ESTIMATION SHEET

Table 17 - Base case estimate

| BASE CASE ESTIMATE | | | | | | |
|---|---|---|---|---|---|---|
| CIVIL WORKS | | DESCRIPTION | QUANTITY | UNITS | RATE | TOTAL COST |
| | **EARTHWORK** | 1) The rates quoted for various items in this section shall be deemed to include for :<br>i) Setting Out works<br>ii) Site clearing such as removing grass and vegetation<br>iii) Bailing out or pumping out subsurface/ rain water in excavation<br>iv) Taking Block Levels prior to the excavation of soft rock/hard rock for measurement<br>v) Providing Shoring, Strutting for protecting the sides of the foundation wherever required<br>2) The classification of soil shall be as per B.I.S provisions. | | | | |
| | WHOLE AREA EXCAVATION | | 1835.00 | cu.m | 240.60 | 441,501 |
| | FOOTING | Earthwork in excavation in **foundation and trenches** etc. in all kinds of soil (excluding soil containing 50% or more of shingle or small size boulders up to 30 cm size, saturated soil and rock), lift of up to 1.5m and stacking the excavated soil not more than 3 m clear from the edge of the excavation and returning the stacked soil in 15 cm layers, when required into plinth | 180.00 | cu.m | 240.60 | 43,308 |
| | PLINTH BEAM | same as above | 62.00 | cu.m | 240.60 | 14,917 |
| | REFILL | Supply and filling in and around the plinth, trenches, sides of foundations, under floors, low lying areas etc., in layers not exceeding 150 mm thick including breaking clods, watering, compacting each layer with heavy Rammers (and at inaccessible placesSupply and filling in and around the plinth, trenches, sides of foundations, under floors, low lying areas etc., in layers not exceeding 200 mm thick including breaking clods, watering, compacting each layer with heavy Rammers (and at inaccessible places with wooden/steel rammers) to achieve 90 to 95% proctor density at optimum moisture content, all leads and lifts, bailing/pumping out of water to keep site dry while back filling; costs includes conveyance of all materials, labour, machinery etc. complete as directed, with:<br><br>a) Approved good quality excavated earth available at site. | 290 | cu.m | 190.00 | 55,100 |
| | **ANTITERMITE** | Column Pits, Wall Trenches, Plinth Filling, Junction of Wall and Floor,<br>Expansion Joints, Surroundings of Pipes, Conduits, along the Perimeter of the<br>Building and all joints in floors, etc. complete, as per the instructions of the<br>Engineer in Charge.<br>(For Billing, only GROUND FLOOR Plinth Area of the building shall be measured), and in accordance with IS 6313 Part II, 1971, and any amendments thereof.<br>The Work shall be carried out through a pest control agency approved by the Architect/Employer, as for example, Pest Control (India) Ltd.,<br>Stages and Dosages of Chemicals used to be as follows:<br>a) Excavated Walls, Column Pits, etc. and at junctions of walls : 1 ltr/linear meter.<br>b) Before laying PCC 1:4:8 below floors after refilling and compaction of the earth : 5 ltr. / Square Meter.<br>c) Along external wall perimeter upto a depth of 300 mm : 4.5 ltr/linear meter. | 367 | sq.m | 100 | 36700 |
| | **PCC** | Providing and laying in position plain cement concrete of specified grade<br>including the cost of centering and shuttering for ALL WORKS UPTO PLINTH LEVEL,<br>including sub grade preparation,levelling, all leads & lifts, rough finishing at the top surface, curing etc., with: | | | | |
| | FOOTING | PCC 1:4:8 (1 cement: 4 river sand: 8 graded stone aggregate 40 mm nominal size) below foundation and flooring. | 15.00 | cu.m | 4,759.90 | 71,399 |
| | FLOORS | | 294.00 | cu.m | 4,759.90 | 1,399,411 |
| | SILL CONCRETE | For Plain window sills | 5.00 | cu.m | 10,884.50 | 54,423 |
| | FLAGGING | PCC 1:3:6 (1 cement: 3 river sand: 6 graded stone aggregate mm nominal size) | 1924 | cu.m | 1141 | 2,195,284 |
| | TOILET | PCC 1:3:6 (1 cement: 3 river sand: 6 graded stone aggregate | 21 | cu.m | 6817 | 143,157 |
| | **RCC** | Providing and laying in position R.C.C of following grades in | | | | |
| | FOOTING | Reinforced concrete work in foundations, footings, bases of columns etc. and mass concrete excluding cost of centring, shuttering and reinforcement in<br>M20 (1 cement: 1.5 coarse sand: 3 stone aggregate 20 mm nominal size). | 128.00 | cu.m | 7180.2 | 919,066 |
| | PEDESTAL | | 54.00 | cu.m | 8179 | 441,666 |
| | COLUMN | Reinforcement cement concrete work in columns, pillars, piers, abutments, post and<br>struts etc up lo floor lwo level including finishing and plastering the exposed surface<br>with cement mortar 1: 3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to<br>give a smooth and even suiface but exluding cost of centring, shuttering. and<br>reinforcement | 73.00 | cu.m | 9063.4 | 661,628 |
| | PLINTH BEAM | surface but excluding cost of centering, shuttering and reinforcement. | 18.00 | cu.m | 6358.7 | 114,457 |
| | BEAMS | M20 (1 cement. 1.5 coarse sand: 3 stone aggregale 20 mm | 155.00 | cu.m | 8966 | 1,389,730 |
| | LINTELS | nominal size) | 9.00 | cu.m | 8,966.00 | 80,694 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | STAIRCASES | Reinforced cement concrete work in stair cases (excluding landing)<br>including finishing and plastering the exposed surface with cement mortar 1: 3 (1<br>cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even<br>surface, preparing of the top surface and finishing, nosing upto floor two level but<br>excluding the cost of centring, shuttering and reinforcement with M20 (1 cement: 1.5<br>coarse sand : 3 stone aggregate 20 mm nominal size). | 82.00 | cu.m | 10051.9 | 824,256 |
| | OHT 1 - DOMESTIC | | 10,000.00 | litre | 7 | 70,000 |
| | OHT 2 - MUNICIPALWATER | | 13000 | litre | 7.00 | 91,000 |
| | SUMP TANK | | 27000 | litre | 6.00 | 162,000 |
| | SHEAR WALLS | | 131 | cu.m | 7,884.00 | 1,032,804 |
| | RETAINING WALL | | 23.00 | cu.m | 7,884.00 | 181,332 |
| | PLAIN SLAB | | 495.00 | cu.m | 6423.35 | 3,179,558 |
| | **MASONRY** | 1) The rates are inclusive of providing and removing scaffolding wherever required, and curing<br>2) In case of Brick/Concrete Block masonry, the thickness of mortar joints should not exceed 10 mm.<br>3) Testing of Bricks and Concrete Blocks shall be carried out as and when required and test results shall be produced.<br>4) Rate should be inclusive lead and lift of all necessary materials to required level | | | | |
| | | Providing and constructing AAC blocks in cement 1:4 for all leads and lifts | 576.00 | cu.m | 5,190.00 | 2,989,440 |
| | **SHUTTERING** | Centring and shuttering including strutting, proping etc. and removal of form work for walls, columns and beams | | | | |
| | WALL | | 5,007.00 | | 670 | 3,354,690 |
| | COLUMNS | | 588.00 | sq.m | 348.50 | 204,918 |
| | BEAMS | | 4,789.00 | sq.m | 474.80 | 2,273,817 |
| | **REINFORCEMENT (4KG/SQFT)** | Reinforcement for RCC work including bending, binding and placing in position<br>complete. | | | | |
| | STEEL | | 176160 | kg | 86.60 | 15,255,456 |
| | **PLASTERING** | The rate quoted shall include the cost of:<br>i) Providing & removing the scaffolding wherever required, and curing<br>ii) Providing arpita mesh for a width of 150 mm at the junctions of masonry walls and RCC works at all heights.<br>iii) Making grooves, patties & drip moulds in chajjas and slab projections.<br>iv) In case of columns & beams only exposed faces shall be considered for plastering under columns and beams<br>v) The rate quoted shall include the cost of chipping and finishing the wall surface after skirting is completed. | | | | |
| | EXTERIOR WALLS | 15 mm Cement Plaster - 1:4 (1 cement : 4 fine sand )inclusive of waterproof compound mix | 399.00 | sq.m | 172.70 | 68,907 |
| | INTERIOR WALLS | 12 mm Cement Plaster - 1:6(1 cement : 6 fine sand ) | 1,937.00 | sq.m | 146.00 | 282,802 |
| | PARAPET | 15 mm Cement Plaster - 1:4 (1 cement : 4 fine sand )inclusive of waterproof compound mix | 100.00 | sq.m | 172.70 | 17,270 |
| | CEILING | 6 mm Cement Plaster - 1:6 (1 cement : 4 fine sand )inclusive of waterproof compound mix | 3,383.00 | sq.m | 130.80 | 442,496 |
| | **PAINTING** | The rate quoted shall include the cost of:<br>i) Providing & removing the scaffolding wherever required, and curing<br>ii) Providing arpita mesh for a width of 150 mm at the junctions of masonry walls and RCC works at all heights.<br>iii) Making grooves, patties & drip moulds in chajjas and slab projections.<br>iv) In case of columns & beams only exposed faces shall be considered for plastering under columns and beams<br>v) The rate quoted shall include the cost of chipping and finishing the wall surface after skirting is completed. | | | | |
| | EXTERIOR WALLS | Emulsion Paint | 399.00 | sq.m | 161.46 | 64,423 |
| | INTERIOR WALLS | Emulsion Paint | 1,937.00 | sq.m | 158.00 | 306,046 |
| | PARAPET | Emulsion Paint | 119.00 | sq.m | 161.46 | 19,214 |
| | CEILING | Emulsion Paint | 3,383.00 | sq.m | 158.00 | 534,514 |
| | **FLOORING** | 1) The rate includes provision of selected flooring material DELIVERED AT SITE, including cost of loading / unloading and transport.<br>2) All necessary protective measures like covering the floor with supply and spreading of P.O.P with polythene sheet below P.O.P and removing and cleaning of the same<br>3) If the bed mortar thickness increases beyond the specified thickness then the level difference shall be made up by providing screed concrete | | | | |
| | GRANITE | For all areas and spaces | 2569 | sqm | 1200 | 3,082,800 |
| | CERAMIC TILES | For all toilets | 112 | sqm | 795.5 | 89,096 |
| | CONCRETE | For Basements | 367 | sqm | 6638 | 2,436,146 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **ROOFING** | Providing INTEGRAL CEMENT BASED WATER PROOFING treatment over RCC roof terrace by spreading cement slurry over the RCC slab and laying 100 mm thick average thickness using table moulded half bricks and proprietary water proofing compound , at all levels.<br>This is to be mixed with cement and sand to Proprietary Firm's composition, laid to required gradient to have easy flow of rain water, and top finished with water proof jointless Plaster finished smooth with wooden trowels with false marking of 300 sq.mm<br>This includes rounding off of junctions of walls and slabs. The treatment should carry 10 years of performance guarantee.<br>The rate includes complete items, including labour and materials and any initial treatment for filling up honeycombs and crevices in the RCC slabs if found necessary.<br>The rate shall be for finished area treated including vertical surfaces. | | | | |
| | WATERPROOFING | | 376 | sq.m | 430.9 | 162,018 |
| | **MISCELLANEOUS** | | | | | |
| | MS HANDRAILS | For Staircases | 127.80 | rmt | 128.40 | 16,410 |
| | DOORS | Alluminium Door | 75.00 | no | 8,333.00 | 624,975 |
| | LIFT | Installation of lift per landing and lift equipment | 2.00 | no | 1,400,000.00 | 2,800,000 |
| | AIR CONDITION | Capacity - 1.5 TON | 7.00 | no | 43,999.00 | 307,993 |
| | AIR CONDITION | Capacity - 2 TON | 8.00 | no | 56,990.00 | 455,920 |
| | FALSE CEILING | 12 MM POP | 1,493.00 | sq.m | 1,388.00 | 2,072,284 |
| | KITCHEN COUNTER | In kitchen | 8.00 | sq.m | 4,000.00 | 32,000 |
| | GLASS | Curtain Wall | 484.40 | sqm | 5,545.00 | 2,685,998 |
| | | Window | 322.56 | sqm | 1,335.00 | 430,618 |
| | **TOTAL OF CIVIL WORKS** | | | | | **54,613,640** |

Table 18 - Proposed case project estimate

| PROPOSED CASE ESTIMATE | | | | | | |
|---|---|---|---|---|---|---|
| CIVIL WORKS | | DESCRIPTION | QUANTITY | UNITS | RATE | TOTAL COST |
| | **EARTHWORK** | 1) The rates quoted for various items in this section shall be deemed to include for :<br>i) Setting Out works<br>ii) Site clearing such as removing grass and vegetation<br>iii) Bailing out or pumping out subsurface/ rain water in excavation<br>iv) Taking Block Levels prior to the excavation of soft rock/hard rock for measurement<br>v) Providing Shoring, Strutting for protecting the sides of the foundation wherever required<br>2) The classification of soil shall be as per B.I.S provisions. | | | | |
| | WHOLE AREA EXCAVATION | | 1758.04 | cu.m | 240.60 | 422,984 |
| | FOOTING | Earthwork in excavation in **foundation and trenches** etc. in all kinds of soil (excluding soil containing 50% or more of shingle or small size boulders up to 30 cm size, saturated soil and rock), lift of up to 1.5m and stacking the excavated soil not more than 3 m clear from the edge of the excavation and returning the stacked | 1,403.47 | cu.m | 240.60 | 337,675 |
| | PLINTH BEAM | Same as above | 289.28 | cu.m | 240.60 | 69,601 |
| | REFILL | Supply and filling in and around the plinth, trenches, sides of foundations, under floors, low lying areas etc., in layers not exceeding 150 mm thick including breaking clods, watering, compacting each layer with heavy Rammers (and at inaccessible placesSupply and filling in and around the plinth, trenches, sides of foundations, under floors, low lying areas etc., in layers not exceeding 200 mm thick including breaking clods, watering, compacting each layer with heavy Rammers (and at inaccessible places with wooden/steel rammers) to achieve 90 to 95% proctor density at optimum moisture content, all leads and lifts, bailing/pumping out of water to keep site dry while back filling; costs includes conveyance of all materials, labour, machinery etc. complete as directed, with:<br><br>a) Approved good quality excavated earth available at site. | 2467.44 | cu.m | 190.00 | 468,814 |
| | **ANTITERMITE** | Column Pits, Wall Trenches, Plinth Filling, Junction of Wall and Floor,<br>Expansion Joints, Surroundings of Pipes, Conduits, along the Perimeter of the<br>Building and all joints in floors, etc. complete, as per the instructions of the<br>Engineer in Charge.<br>(For Billing, only GROUND FLOOR Plinth Area of the building shall be measured), and in accordance with IS 6313 Part II, 1971, and any amendments thereof.<br>The Work shall be carried out through a pest control agency approved by the Architect/Employer, as for example, Pest Control (India) Ltd.,<br>Stages and Dosages of Chemicals used to be as follows:<br>a) Excavated Walls, Column Pits, etc. and at junctions of walls : 1 ltr/linear meter.<br>b) Before laying PCC 1:4:8 below floors after refilling and compaction of the earth : 5 ltr. / Square Meter.<br>c) Along external wall perimeter upto a depth of 300 mm : 4.5 ltr/linear meter. | 1494.9 | sq.m | 50 | 74,745 |
| | **FOUNDATION** | PILE FOUNDATIION - Incldes cost of PRE FABRICATION , SURVEY TEAM TOPOGRAPHY AND PILE MARKING - TOOLS AND PLANS NEEDED | | | | |
| | PRE CAST SHORT PILES | | 1594 | no. | 6801 | 10,840,794 |
| | **PCC** | Providing and laying in position plain cement concrete of specified grade<br>including the cost of centering and shuttering for ALL WORKS UPTO PLINTH LEVEL,<br>including sub grade preparation,levelling, all leads & lifts, rough finishing at the top surface, curing etc., with: | | | | |
| | FOOTING | PCC 1:4:8 (1 cement: 4 river sand: 8 graded stone aggregate 40 mm nominal size) below foundation and flooring. | 26.14 | cu.m | 4,759.90 | 124,424 |
| | FLOORS | | 164.90 | cu.m | 4,759.90 | 784,908 |
| | SILL CONCRETE | For Plain Window Sills | 4.67 | cu.m | 10,884.50 | 50,831 |
| | TOILET | PCC 1:3:6 (1 cement: 3 river sand: 6 graded stone aggregate 40 mm nominal size) below foundation and flooring. | 18.95 | cu.m | 6,817.00 | 129,169 |
| | **RCC** | Providing and laying in position R.C.C of following grades in components and at locations as given below, including the cost of all materials (including admixtures approved by consultants), preparation, laying compacting and curing of concrete ,with all leads, lifts,, vibrating where ever necessary ,curing as directed and including the cost of shuttering / centering but excluding the cost of reinforcement steel which shall be quoted separately.The design mix may be prepared at site by weight - batching or obtained as ready mix concrete from source approved by the Engineer in charge/architect/owner.<br>Difference in rates for readymix and site mix concrete per cubic metre shall be mentioned.<br>Permisible Limit of Concrete Quantity by manual mix at single pour shall not be more than 6 cum. | | | | |
| | FOOTING | Reinforced concrete work in foundations, footings, bases of columns etc. and mass concrete excluding cost of centring, shuttering and reinforcement inM20 (1 cement: 1.5 coarse sand: 3 stone aggregate 20 mm nominal size). | 431.76 | cu.m | 7180.2 | 3,100,123 |
| | PEDESTAL | | 179.94 | cu.m | 8179 | 1,471,729 |
| | COLUMN | Reinforcement cement concrete work in columns, pillars, piers, abutments, post and struts etc up lo floor two level including finishing and plastering the exposed surface with cement mortar 1: 3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even suiface but exluding cost of centring, shuttering. and reinforcement | 262.07 | cu.m | 9063.4 | 2,375,263 |
| | PLINTH BEAM | Reinforced cement concrele work in lintels, beams and bresumers up to floor level including finishing and plastering the exposed surface with cement mortar 1: 3 /1 cement: 3 fine sand) of thickness not exceeding 6 mm lo give a smooth and even surface | 108.48 | cu.m | 6358.7 | 689,792 |
| | BEAMS | | 143.46 | cu.m | 8966 | 1,286,262 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | LINTELS | but excluding cost of centering, shuttering and reinforcement. M20 (1 cement. 1.5 coarse sand: 3 stone aggregale 20 mm nominal size) | 4.68 | cu.m | 8,966.00 | 41,943 |
| | STAIRCASES | Reinforced cement concrete work in stair cases (excluding landing) including finishing and plastering the exposed surface with cement mortar 1: 3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface, preparing of the top surface and finishing, nosing upto floor two level but excluding the cost of centring, shuttering and reinforcement with M20 (1 cement: 1.5 coarse sand : 3 stone aggregate 20 mm nominal size). | 13.36 | cu.m | 10051.9 | 134,293 |
| | RAMP | Similar to above but for RAMP from Ground to First Floor only | 7.94 | cu.m | 6358.7 | 50,475 |
| | UGT- TANK 1 (RAINWATER) | | 150 | cu.m | 6,891.00 | 1,033,650 |
| | UGT - TANK 2 (MUNICIPAL WATER TANK) | | 7.5 | cu.m | 6,891.00 | 51,683 |
| | UGT - TANK 3 (FILTERED GREY WATER) | | 5 | cu.m | 6,891.00 | 34,455 |
| | STP | | 7.70 | KLD | - | 385,000 |
| | BIO DIGESTOR | | 8216 | litres | | 25,000 |
| | UG FOOD STORAGE | | 13.55 | cu.m | 6,891.00 | 93,352 |
| | UG FOOD STORAGE PIPE | | 2.67 | sqm | 800.00 | 2,136 |
| | WAFFLE SLAB | | 168.78 | cu.m | 6723.84 | 1,134,850 |
| | PLAIN SLAB | | 855.02 | cu.m | 6423.35 | 5,492,112 |
| | **MASONRY** | 1) The rates are inclusive of providing and removing scaffolding wherever required, and curing<br>2) In case of Brick/Concrete Block masonry, the thickness of mortar joints should not exceed 10 mm.<br>3) Testing of Bricks and Concrete Blocks shall be carried out as and when required and test results shall be produced.<br>4) Rate should be inclusive lead and lift of all necessary materials to required level | | | | |
| | COMPRESSED STABILIZED EARTH BLOCKS | Providing and constructing SCEB blocksin cement 1:4 for all leads and lifts inclusive of cost of bamboo reinforcement<br>(bamboo shall be measured and paid for seperately) | 602.20 | cu.m | 1,667.00 | 1,003,867 |
| | **SHUTTERING** | Centring and shuttering including strutting, proping etc. and removal of form work for columns and beams | | | | |
| | COLUMNS | | 1,973.88 | sq.m | 348.50 | 687,897 |
| | BEAMS | | 3,857.16 | sq.m | 474.80 | 1,831,380 |
| | **REINFORCEMENT** | Reinforcement for RCC work including bending, binding and placing in position complete. | | | | |
| | STEEL | | 230340 | kg | 86.60 | 19,947,444 |
| | BAMBOO | | 10084 | m | 27.80 | 280,335 |
| | **PLASTERING** | The rate quoted shall include the cost of:<br>i) Providing & removing the scaffolding wherever required, and curing<br>ii) Providing arpita mesh for a width of 150 mm at the junctions of masonry walls and RCC works at all heights.<br>iii) Making grooves, patties & drip moulds in chajjas and slab projections.<br>iv) In case of columns & beams only exposed faces shall be considered for plastering under columns and beams<br>v) The rate quoted shall include the cost of chipping and finishing the wall surface after skirting is completed. | | | | |
| | EXTERIOR WALLS | 15 mm Cement Plaster - 1:4 (1 cement : 4 fine sand )inclusive of waterproof compound mix | 72.89 | sq.m | 172.70 | 12,588 |
| | INTERIOR WALLS | 12 mm Cement Plaster - 1:6(1 cement : 6 fine sand ) | 1,745.14 | sq.m | 146.00 | 254,791 |
| | PARAPET | 15 mm Cement Plaster - 1:4 (1 cement : 4 fine sand )inclusive of waterproof compound mix | 259.31 | sq.m | 172.70 | 44,783 |
| | CEILING | 6 mm Cement Plaster - 1:6 (1 cement : 4 fine sand )inclusive of waterproof compound mix | 4,603.28 | sq.m | 130.80 | 602,109 |
| | **PAINTING** | The rate quoted shall include the cost of:<br>i) Providing & removing the scaffolding wherever required, and curing<br>ii) Providing arpita mesh for a width of 150 mm at the junctions of masonry walls and RCC works at all heights.<br>iii) Making grooves, patties & drip moulds in chajjas and slab projections.<br>iv) In case of columns & beams only exposed faces shall be considered for plastering under columns and beams<br>v) The rate quoted shall include the cost of chipping and finishing the wall surface after skirting is completed. | | | | |
| | OIL BOUND DISTEMPER PAINT | For ceiling | 4,603.28 | sq.m | 30.60 | 140,860 |
| | EMULSION PAINT | For internal walls,external walls and parapets | 2,077.34 | sq.m | 161.46 | 335,407 |
| | ENAMEL PAINT | For all metal works for box section | 318.20 | sq.m | 33.50 | 10,660 |
| | | For door and windows | 565.79 | sq.m | 33.50 | 18,954 |
| | WHITE PAINT | For roofs | | sq.m | 7.00 | |
| | **POLISHING** | The rate qouted shall include rate of polishing inclusive of material | | | | |
| | DOORS AND WINDOWS | | 565.79 | sqm | 48.30 | 27,327 |
| | **FLOORING** | 1) The rate includes provision of selected flooring material DELIVERED AT SITE, including cost of loading / unloading and transport.<br>2) All necessary protective measures like covering the floor with supply and spreading of P.O.P with polythene sheet below P.O.P and removing and cleaning of the same<br>3) If the bed mortar thickness increases beyond the specified thickness then the level difference shall be made up by providing screed concrete | | | | |
| | LINOLEUM | For all areas in all spaces | 4,603.28 | sqm | 807.31 | 3,716,274 |
| | FLAME GRANITE | For ramp flooring area | 52.92 | sqm | 968.78 | 51,268 |
| | GRANITE | For verhanda steps , DA ramp , staircases | 117.65 | sqm | 1200 | 141,180 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | CERAMIC TILES | For toilets | 189.48 | sqm | 795.5 | 150,731 |
| | STONE PAVERS | For landscaping | 134.08 | sqm | 2029 | 272,048 |
| | TERRAZO TILES | For all terrace spaces | 227.894 | sqm | 1098.6 | 250,364 |
| | SKIRTING | For all rooms and corridors | 2893.98 | rmt | 125 | 361,748 |
| | DADO | In toilets and kitchen | 220.73 | sq.m | 125 | 27,591 |
| | **ROOFING** | Providing INTEGRAL CEMENT BASED WATER PROOFING treatment over RCC roof terrace by spreading cement slurry over the RCC slab and laying 100 mm thick average thickness using table moulded half bricks and proprietary water proofing compound , at all levels.<br>This is to be mixed with cement and sand to Proprietary Firm's composition, laid to required gradient to have easy flow of rain water, and top finished with water proof jointless Plaster finished smooth with wooden trowels with false marking of 300 sq.mm<br>This includes rounding off of junctions of walls and slabs. The treatment should carry 10 years of performance guarantee.<br>The rate includes complete items, including labour and materials and any initial treatment for filling up honeycombs and crevices in the RCC slabs if found necessary.<br>The rate shall be for finished area treated including vertical surfaces. | | | | |
| | WATERPROOFING | | 227.894 | sq.m | 430.9 | 98,200 |
| | **MISCELLANEOUS** | | | | | |
| | MS HANDRAILS | For Staircases | 42.66 | rmt | 128.40 | 5,478 |
| | DOORS AND WINDOWS | 1) The rate quoted for the following items in this group shall be for:<br>a) Finishing of the openings / damages done during fixing of the same.<br>b) Providing and fixing hold fast,necessary chipping,and making the surface good after fixing.<br>c)Ensuring the protection of all wooden frame members as necessary, prior to handing over. | 565.79 | sqm | 490.70 | 277,631 |
| | FINS | Built up C Section Bracket | 114.55 | kg | 513.9 | 58868.2728 |
| | | Baamboo Mat | 299.60 | m | 45.00 | 13,482 |
| | LIGHT WEIGHT CEMENT CLADDING WITH MOSS | TYPE 1 - 4.8mx 1.2m | 8.64 | cu.m | 4032 | 34836.48 |
| | | TYPE 2- 4.2m x 0.9m | 1.0395 | cu.m | 2646 | 2750.517 |
| | FALSE CEILING | Made of Plaster Of Paris | 338.98 | sq.m | 951.00 | 322,370 |
| | SKYLIGHTS | Polycarbonate sheet 2 mm | 91.80 | sqm | 800.00 | 73,440 |
| | | Steel framework- Installation cost | 515.00 | kg | 86.67 | 44,635 |
| | KITCHEN COUNTER | Marble counter tops | 9.70 | sq.m | 4,000.00 | 38,800 |
| | WICKER BASKETS | For Waffle slabs, as pods | 390 | no. | 88.00 | 34,320 |
| | PLANTER BOX | Made of wood | 32 | no. | 120.00 | 3,840 |
| | | Made of concrete | 4.05 | no. | 6,423.35 | 26,015 |
| | OHT - TANK 1 (DOMESTIC WATER TANK) | | 5,000.00 | ltr | 37,500.00 | 37,500.00 |
| | OHT - TANK 2 (DOMESTIC WATER) | | 3,000.00 | ltr | 22,500.00 | 22,500.00 |
| | OHT - TANK (IRRIGATION WATER) | | 2,000.00 | ltr | 15,000.00 | 15,000.00 |
| | LABOUR TRAINING | Cost of knowledge transfer (Proffesional Sum) | | | | 15,000 |
| | **TOTAL OF CIVIL WORKS** | | | | | 62,000,334 |
| **MEP WORKS** | | | | | | |
| | **EQUIPMENT COSTING** | AS MENTIONED IN THE REPORT | | | | |
| | SOLAR PANELS | | 180 | no. | 21000 | 3780000 |
| | SOLAR PANELS INSTALLATION -PANEL STAND | | 60 | no. | 10500 | 630000 |
| | LITHIUM PHOSPHATE BATTERIES | | 60 | no. | 250000 | 15000000 |
| | BLDC FANS | | 108 | no. | 3270 | 353160 |
| | AIR TURBINE ROOF VENTILATOR | | 3 | no. | 4000 | 12000 |
| | EXHAUST FANS | | 7 | no. | 2250 | 15750 |
| | PRAYER WHEELS | | 118 | no. | 2000 | 236000 |
| | INVERTER | | 1 | no. | 237552 | 237552 |
| | LIFT EQUIPMENT | | 1 | no. | 550000 | 550000 |
| | SPROCKET | | 118 | no. | 300 | 35400 |
| | CHAIN | | 2 | no. | 5000 | 10000 |
| | GEARS | | 2 | no. | 12000 | 24000 |
| | GDYNAMO | | 2 | no. | 7000 | 14000 |
| | **LIGHTING COSTING** | AS MENTIONED IN THE REPORT | | | | |
| | LED BATTENS- 36W | | 384 | no. | 950 | 364800 |
| | LED DOWNLIGHTS - 10W | | 78 | no. | 850 | 66300 |
| | OUTDOOR LIGHTING (TERRACES) | | 10 | no. | 950 | 9500 |
| | POINT WIRING FOR SWITCH BOARDS (provisional) | | 800 | no. | 750 | 600000 |
| | EARTHING PITS | Providing, installing, testing and commissioning of GI pipe earthing station including excavation, back filling,earthing strips as per code, 38mm internal diameter GI pipe of 2.5 mts long, construction of inspection chamber (CI) - heavy duty, disconnecting linketc., as per IS 3043 Supply & Installation | 4 | no. | 4000 | 16000 |
| | LIGHTING SOCKETS | 6A | 135 | no. | 80 | 10800 |
| | FAN POWER SOCKETS | Ceiling fan point controlled by Step type electronic modular regulator | 56 | no. | 80 | 4480 |
| | POWER SOCKETS | 6A | 50 | no. | 80 | 4000 |
| | | 16A | 10 | no. | 122 | 1220 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **WATER PERFORMANCE EQUIPMENT COSTING** | AS MENTIONED IN THE REPORT | | | | |
| | RWH PUMP | | 1 | no. | 20000 | 20000 |
| | MUNCIPAL WATER PUMP | | 1 | no. | 20000 | 20000 |
| | IRRAGTION PUMP | | 1 | no. | 7000 | 7000 |
| | ECO STP | | 1 | no. | 385000 | 385000 |
| | DRINKING WATER FILTERS | | 1 | no. | 17000 | 17000 |
| | KITCHEN FAUCET | Installing, testing and commissioning of stainless steel sink manufactured from 1mm thick, stainless steel, ISG high grade indestructible chrome nickel steel with top quality polish, 40mm dia CP waste coupling, with 32mm dia waste pipe up to flour trap below, 15mm dia sink cock with swivel spout wall mounted type, with necessary wall flanges etc. complete. Make : NIRALLI / DIAMOND, double pan, 4'x2' , SS material with complete accessories. | 4 | no. | 2000 | 8000 |
| | URINALS | Supply, Installing, testing and Commissioning if White glazed Urinals complete with all other required accssories etc., | 3 | no. | 11830 | 35490 |
| | WATER CLOSET | Supplying, installing, testing and commissioning of white glazed Floor mounted European water closet with ceramic body cistern as mentioned on the drawings with necessary bend, checknut, stopcock etc., colour solid seat and cover with polythene buffer and flap, CP flanges, CP bolts and nuts, a pair of CI chair bracket with nuts and bolts, wall flanges etc., complete. | 30 | no. | 13445 | 403350 |
| | WASH BASIN FAUCET | | 32 | no. | 4600 | 147200 |
| | WATER PUMP (1HP) | | 1 | no. | 7000 | 7000 |
| | WATER PUMP (2HP) | | 2 | no. | 20000 | 40000 |
| | RW DOWN TAKE PIPES | FINOLEX PVC - 160mm dia, 12m long pipes | 9 | no. | 150 | 1350 |
| | SOIL PIPE | FINOLEX PVC - 110 dia, 6m long pipes | 90 | no. | 185 | 16650 |
| | GREY WATER PIPES | FINOLEX PVC - 75 dia, 6m long pipes | 78 | no. | 130 | 10140 |
| | WATER INLET PIPES | ASTRAL CPVC - 50 dia, 5m long pipes<br>Supply, installation and comissioning of CPVC ASTM D26 pipes for hot & cold water supply with Malleable Specials suchas tees, elbows,check nuts, unions, flanges,nipples, etc | 55 | no. | 2380 | 130900 |
| | RO WATER PURIFIER | | 1 | no. | 17000 | 17000 |
| | PORTABLE COLLAPSIBLE TOILETS | | 10 | no. | 15000 | 150000 |
| | **TOTAL OF PHE WORKS** | | | | | 23,391,042 |
| **INTERNAL / FURNITURE WORKS** | | | | | | |
| | **FURNITURE COSTING** | 1) The rate quoted for the following items in this group shall be for:<br>a) Material cost<br>b) Labor caost | | | | |
| | SMALL SIZED TABLE | Made of WOOD - 1.5mx 1.5m , 0.7m height | 20 | no. | 1535 | 30700 |
| | RECEPTION TABLE | Made of WOOD - 2400mmx 650mm, 750 hight | 4 | no. | 9499 | 37996 |
| | CENTRE TABLES | Made of WOOD Frame with GLASS - 900mmx460mm, 480mm heig | 11 | no. | 2425 | 26675 |
| | LARGE SIZED TABLE | Made of STEEL- 2400mmx 1200mm, 750mm ht | 18 | no. | 8299 | 149382 |
| | CONFERENCE TABLE | Made of WOOD - 3200mmx1200mm , 750 ht | 2 | no. | 10147 | 20294 |
| | DESKS | Made of WOOD - 1500mmx 650mm, 750ht | 78 | no. | 6299 | 491322 |
| | TABLE OR CHILDREN | Made of WOOD - 800dia, 630mm ht | 2 | no. | 4500 | 9000 |
| | CHAIRS | Made of WOOD - 500mmx 480mm, 450mm ht of seat and 800mm ht of backrest | 111 | no. | 1200 | 133200 |
| | OFFICE CHAIRS | Fabric/ Faux leather/ Vinyl + Steel base + Cushion | 99 | no. | 4395 | 435105 |
| | SOFA - 3 SEATER | Made of WOOD Frame with FABRIC | 10 | no. | 12000 | 120000 |
| | SOFA - 1 SEATER | Made of WOOD Frame with FABRIC | 14 | no. | 8000 | 112000 |
| | CHAIR FOR CHILDREN | Made of WOOD - 500mmx 480mm, 450mm ht of seat and 800mm ht of backrest | 24 | no. | 1600 | 38400 |
| | LOCKERS | Made of WOOD - 800mmx450mm, 450ht , 16 door workers locker | 7 | no. | 16000 | 112000 |
| | WARDROBE CLOSETS | Made of WOOD - 800mmx 450mm, 2100mm ht | 19 | no. | 4000 | 76000 |
| | SINGLE BEDS | Made of WOOD | 5 | no. | 5000 | 25000 |
| | HOSPITAL COT | Rexine/ Plastic + Steel + Mattress | 4 | no. | 3850 | 15400 |
| | AUDITORIUM CHAIRS | Made of Arjuna Wood | 2663.68 | cu.m | 2135 | 5686956.8 |
| | WORKSHOP CHAIRS | Made of Arjuna Wood | 9840 | cu.m | 2135 | 21008400 |
| | CARDBOARD BEDS | Bunk Beds made of Cardboard | 9389 | cu.m | 110 | 1032790 |
| | MATTRESS | | 5766 | cu.m | 749 | 4318734 |
| | **GYM** | | | | | |
| | TREADMILL | | 4 | no. | 9275 | 37100 |
| | TRAINING BENCH | | 3 | no. | 1151 | 3453 |
| | STATIONARY BICYCLE | | 5 | no. | 4599 | 22995 |
| | ELLIPTICAL CROSS TRAINER | | 3 | no. | 8490 | 25470 |
| | CHEST PRESS MACHINE | | 1 | no. | 8053 | 8053 |
| | ARM CURL MACHINE | | 2 | no. | 7955 | 15910 |
| | **TOTAL OF INTERNAL WORKS** | | | | | 33,992,335.80 |
| | **SITE DEVELOPMENT** | | | | | 3027727 |
| | **LABOUR CESS** | | | | | 605545 |
| | **ADDED CONTINGENCIES** | | | | | 1816636 |
| | **TOTAL OF ESTIMATE OF THE PROJECT** | | | | | **124,833,619.79** |

# 9.9 SUMMARY OF EMBODIED CARBON SHEET

| Base case | | | | | Proposed case | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Wall** | | | | | | | | | |
| **Material** | **Volume per block** | **Blocks per 3439.9 sq.m = 26636** | **Density** | **Weight** | **Material** | **Volume per block** | **Blocks per 3439.9 sq.m = 46323** | **Density** | **Weight** |
| AAC blocks | 0.024 | 639.264 | 600 | 383558.4 | Earth block | 0.013 | 602.199 | 1,324 | 7,97,378 |
| Cement mortar | 0.0012 | 31.9632 | 2080 | 66483.456 | 22% sand | 0.00286 | 132.48378 | 1520 | 201375.3456 |
| Cement plaster | | 41.27892 | 1440 | 59441.6448 | 55% soil | 0.00715 | 331.20945 | 1540 | 510062.553 |
| | | | | | 3%water | 0.00039 | 18.06597 | 997 | 18011.77209 |
| | | | | | 7%cement | 0.00091 | 42.15393 | 1440 | 60701.6592 |
| | | | | | 8%straw | 0.00104 | 48.17592 | 150 | 7226.388 |
| | | | | | Bamboo | 0.15 | 465 | 750 | 348750 |
| | | | | | Cement mortar | 0.0009 | 41.6907 | 2080 | 86716.656 |
| | | | | | | | | | |
| **Flooring** | | | | | | **Area - 2734** | | | |
| Granite | 82.02 | | 2750 | 225555 | Linoleum | 7.587 | | 1100 | 8345.7 |
| Cement screed | 82.02 | | 2200 | 180444 | Adhesive | 2.529 | | 1200 | 3034.8 |
| | | | | | Cement screed | 82.02 | | 2200 | 180444 |
| | | | | | Ceramic tile | 2.052 | | | 222382.248 |
| | | | | | | | | | |
| **Windows** | | | | | | | | | |
| uPVC | 0.150262047 | | 1330 | 199.848522 | Particle board light shelves | 0.12 | | 600 | 72 |
| Glass | 0.072449994 | | 2500 | 181.1249855 | Polycarbonate | 0.187 | | 1200 | 224.4 |
| | | | | | Sal wood | 0.211 | | 720 | 151.92 |
| | | | | | | | | | |
| **Structure** | | | | | | | | | |
| **Column - Base case** | | | | | **Column - Proposed case** | 262.07 | | | |
| Steel rebars | 3.93105 | | 7850 | 30858.7425 | Steel rebars | 3.93105 | | 7850 | 30858.7425 |
| Steel stirrups | 2.09656 | | 7850 | 16457.996 | Steel ties - spacing - 300mm | 2.09656 | | 7850 | 16457.996 |
| Concrete | 256.04239 | | 2400 | 614501.736 | Concrete with 50% flyash | 256.04239 | | | 448074.1825 |
| | | | | | | | | | |
| **Concrete beams** | **423.63** | | | | **Beams** | **423.63** | | | |
| Steel rebars | 6.35445 | | 7850 | 49882.4325 | I sections | 38.44811366 | | 7850 | 301817.6922 |
| steel stirrups | 3.38904 | | 7850 | 26603.964 | Steel rebars | 5.7777 | | 750 | 4333.275 |
| Concrete | 413.88651 | | 2000 | 827773.02 | Steel stirrups | 3.08144 | | 7850 | 24189.304 |
| | | | | | Concrete with 50% flyash | 376.3227463 | | 2000 | 752645.4927 |
| | | | | | | | | | |
| | | | | | **Slab** | **3548.48** | | | |
| **One way slab** | **3548.48** | Area-532.27 | | | **Waffle slab** | 177.91 | Total volume | | |
| Steel bars | 5.32272 | | 7850 | 41783.352 | Concrete with 50% flyash | 172.39479 | | 2000 | 344789.58 |
| Concrete | 526.94928 | | 2000 | 1053898.56 | Bamboo pods | 2.84656 | | 750 | 2134.92 |
| | | | | | Steel | 2.66865 | | 7850 | 20948.9025 |
| | | | | | **One way slab** | 531.786 | Total volume | | |
| | | | | | Bamboo bars | 10.63572 | | 750 | 7976.79 |
| | | | | | Steel bars | 2.65893 | | 7850 | 20872.6005 |
| | | | | | Concrete with 50% flyash | 518.49135 | | 2000 | 1036982.7 |
| **Plinth** | | | | | **Plinth** | 1649.98 | Area-164.99 | | |
| Concrete | 162.52303 | | 2000 | 325046.06 | Concrete with 50% flyash | 162.52303 | | 2000 | 325046.06 |
| Steel | 2.47497 | | 7850 | 19428.5145 | Recycled steel | 2.47497 | | 7850 | 19428.5145 |
| | | | | | Total area | 5884.16 | | | |
| | | | | | | | | | |
| **Roof** | | | | | | | | | |
| **One way slab** | 997.98 | 412.334 | | | **Waffle slab** | 118.89 | | | |
| Steel bars | 4.329507 | | 7850 | 33986.62995 | Concrete with 50% flyash | 114.60996 | | 2000 | 229219.92 |
| Concrete | 408.004493 | | 2000 | 816008.986 | Bamboo pods | 1.90224 | | 750 | 1426.68 |
| | | | | 17635.48815 | Steel | 2.3778 | | 7850 | 18665.73 |
| | | | | | **One way slab** | 215.28 | | | |
| | | | | | Steel bars | 1.0764 | | 7850 | 8449.74 |
| | | | | | Bamboo bars | 4.3056 | | 750 | 3229.2 |
| | | | | | Concrete with 50% flyash | 209.898 | | 2000 | 419796 |

Table 19 Material quantities

| System Type | Baseline | | | | Proposed | | | |
|---|---|---|---|---|---|---|---|---|
| | Material emissions ($kg\text{-}CO_2\ e$) | Transport 1 ($kg\text{-}CO_2\ e$) | Transport 2 ($kg\text{-}CO_2\ e$) | Total ($kg\text{-}CO_2\ e$) | Material emissions ($kg\text{-}CO_2\ e$) | Transport 1 ($kg\text{-}CO_2\ e$) | Transport 2 ($kg\text{-}CO_2\ e$) | Total ($kg\text{-}CO_2\ e$) |
| *Wall* | 66.1 | 0.1 | 0.0 | 66.2 | -19.3 | 0.2 | 0.0 | -19.0 |
| *Roof* | 157.2 | 2.6 | 0.1 | 159.9 | 48.2 | 2.7 | 0.2 | 51.1 |
| *Floor* | 37.5 | 0.3 | 0.0 | 37.8 | 18.5 | 0.0 | 0.0 | 18.6 |
| *Fenestration* | 5.1 | 0.0 | 0.0 | 5.1 | 2.3 | 0.0 | 0.0 | 2.4 |
| *Structural* | 182.4 | 2.3 | 0.1 | 184.8 | 91.5 | 4.9 | 0.2 | 96.7 |
| **Grand Total emissions per functional unit** ($kg\text{-}CO_2\ e$) | | | | **453.9** | **Grand Total emissions per functional unit** ($kg\text{-}CO_2\ e$) | | | **149.7** |

Table 20 Carbon emissions per functional unit


Fig xix. Emissions from wall

Fig xx. Emissions from fenestrations

Baseline - 200 x 600 mm AAC blocks with cement mortar
Proposed - 200 x 600 mm Earth blocks(Soil (55%) + Sand (22%) + Straw fibers (8%) + Water (3%) + Cement with 30% fly ash(7%)) with bamboo and fly ash cement mortar

Baseline - 4mm float glass panes with uPVC frame
Proposed - DGU with 2mm polycarbonate and sal wood frame+particle board light shelves

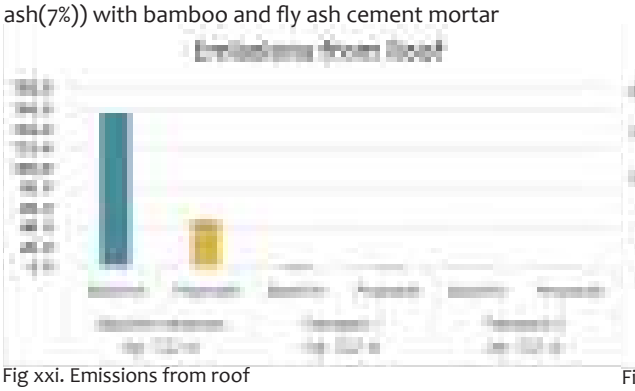


Fig xxi. Emissions from roof

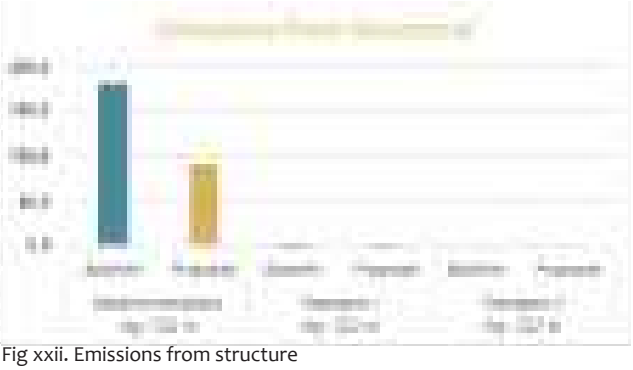
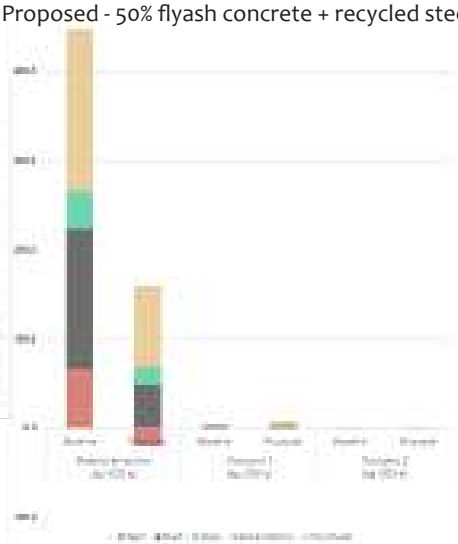


Fig xxii. Emissions from structure

Baseline - 150mm thick RCC slab
Proposed - 150mm thick flyash concrete slab with 50% bamboo and 50% recycled steel reinforcement, waffle slab with bamboo basket pods

Baseline - RCC
Proposed - 50% flyash concrete + recycled steel reinforcement

Fig xxiii. Emissions from floor



According to calculations from the EC tool, carbon emission of materials is reducing by 68%. All materials are available within 300km radius but, due to the non availability of recycled steel near Itanagar, emissions due to transportation from the manufacturer to supplier is more than the baseline.

Baseline - Tan brown 18 mm granite
Proposed - Laminate sheet, ceramic tiles(washrooms) and its wastage(balconies), green pavers(outdoor)

| Material | Manufacturer | Distance | Supplier | Distance |
|---|---|---|---|---|
| Soil | Papumpare | 84 | Naharlagun | 12 |
| Sand | River beds of Himalayas | 258 | Jhorat | 136 |
| Straw bale | East kameng | 94.4 | Chimpu | 4 |
| Fly ash cement | Dimapur | 265 | Itanagar | 5 |
| Water | On site | | | |
| Bamboo | Chimpu forest | 4 | Naharlagun | 10 |
| Cement mortar | Dimapur | 265 | Itanagar | 5 |
| Concrete with 50% fly ash | Dimapur | 265 | Itanagar | 5 |
| Bamboo baskets | Chimpu forest | 4 | Naharlagun | 10 |
| Recycled steel rebars | Jindal steel and power, Chattisgarh | 1850 | Itanagar | 3 |
| Linoleum | Jhorat | 146 | Naharlagun | 12 |
| Flooring adhesive | Jhorat | 146 | Naharlagun | 12 |
| Cement floor screed | Dimapur | 265 | Itanagar | 5 |
| Particle board | Naharlagun | 10 | Itanagar | 2 |
| Polycarbonate sheet | Itanagar | 32 | Itanagar | 4 |
| Sal wood | Pakke tiger reserve | 140 | Naharlagun | 10 |
| Recycled steel sections | Jindal steel and power, Chattisgarh | 1850 | Itanagar | 3 |


Fig xxiv. Sources of materials

# 9.10 BUILDING OPERATION NARRATIVE

## RAIN WATER HARVESTING AND ECOSTP

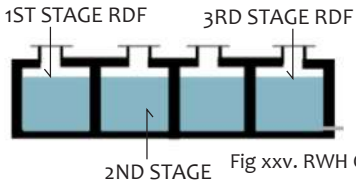



Fig xxv. RWH Operation narrative

**RAIN WATER HARVESTING**
An on-site rainwater harvesting system has been constructed for effective utilization of rainwater. This system consists of down-take pipes, underground storage tanks, sand filters (for the removal of debris and pathogens). It is further treated in an RO filter for potable uses.

**ECOSTP** is a reliable and eco-friendly Zero Power, Zero Odour and Zero Chemical Sewage Treatment Technology. It is a treatment system that lasts for generations with no overground space requirements, daily surveillance, treating the wastewater to pollution control board specifications. It is based on gravity and natural principles with no operators. The sewage flows through multiple chambers and the anaerobic bacteria decomposes the pollutants . It comprises of three separate chambers with rumen digester filters and a final planted bio filter. Once in 2 years or 4 years the sludge has to be removed. It doesn't need dedicated maintenance personnel unlike in conventional technologies since there are no electro – mechanical components involved. The only maintenance required is de-sludging once in 2 years. However we also do Annual Maintenance Contracts (AMC) We do monthly checks on water, engineer visits and annual desludging.

| | |
|---|---|
| POWER SAVED | 6570 KWH/YEAR |
| COAL SAVED | 5.26 TONNE/YEAR |
| ANNUAL SAVINGS | 65,494 |
| ROI ACHIEVED IN | 2 YEARS |

## BIODIGESTER

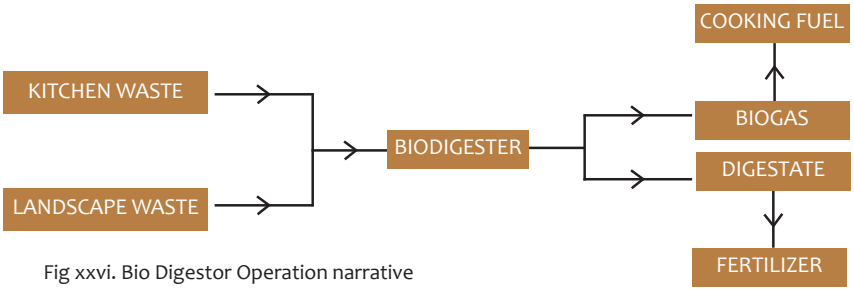



Fig xxvi. Bio Digestor Operation narrative

The aim is to re-purpose majority of the solid waste generated on site or to get it collected by recycling facilities, so that it none of it ends up in the land fill eventually.
The manual procedures involved in supplying kitchen waste to a biodigester are as follows:
a) Segregation of waste: The first step is to categorize kitchen waste into separate groups: food, vegetable, and fruit. This is necessary to ensure the proper nutrient balance is maintained in the biodigester.
b) Waste collection: After segregating the waste, it should be collected and kept in a container or bin.
c) Waste mixing: To make a slurry, it's necessary to combine the kitchen waste with water. This can be accomplished manually by churning the garbage in a container
d) The slurry is manually fed into the biodigester
5)regular inspection and maintenance instructions
The biodigester should be inspected weekly, for any leaks or signs of damage. The inlet and outlet pipes should be checked to ensure that they are not blocked. The quality of biogas should be monitored regularly to ensure that it meets the required standards. The gas pipes should be checked for leaks, and the gas pressure should be checked.
The following are the steps that can be taken during emergency situations to manage solid waste effectively:
a) The segregation of waste is done into different categories such as recyclable, non-recyclable, hazardous, and first-aid medical waste
b) Disaster times, the first-aid medical waste are collected by medical waste management facilities that specialize in collection, treatment and disposal
c) Toxic waste like batteries are collected by toxic waste management facilities that specialize in collection, treatment and disposal
d) The bio degradable waste generated from kitchen at our site, is fed to the bio digestor and bio gas is generated for cooking fuel during disaster times.

## PILE FOUNDATION

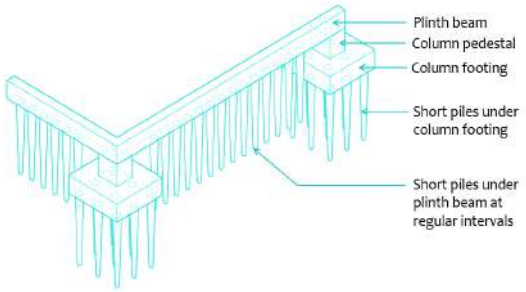



Fig xxvii. Pile foundation narrative

Precast concrete short pile foundation system was chosen for this project to combat with earthquakes. When compared to long piles that are subjected to plastic hinge effect during earthquakes, short piles are much more resilient with this regard.
Short pile foundations are typically less expensive and faster to install than long pile foundations, making them a more cost-effevctive option. We have short piles under the plinth beam in addition to the footing short piles for additional stability.
They also produce less waste during installation and can be easily removed and recycled at the end of their useful life, making them an environmentally

## SOLAR PV PANELS WITH ENERGY-STORAGE SYSTEM ALONG WITH OTHER ENERGY

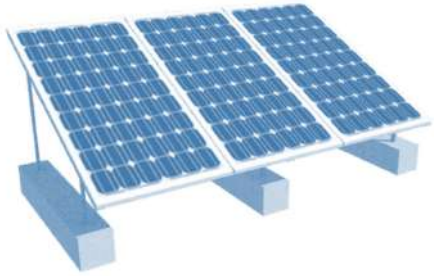


Fig xxviii. Solar PV panel narrative

1. It generates off-grid power using solar panels and lithium phosphate batteries for energy storage, enabling four days of autonomy. In addition, mechanical energy from gym equipment and the power of prayer - Buddhist prayer wheels with a gear system - are used to generate energy.
Everything is executed manually, including operable windows with shading devices tailored to each facade and the installation of energy-efficient fans

## WINDOW WALL RATIO, UNIFORMITY RATIO FOR LIGHTING AND VENTILATION

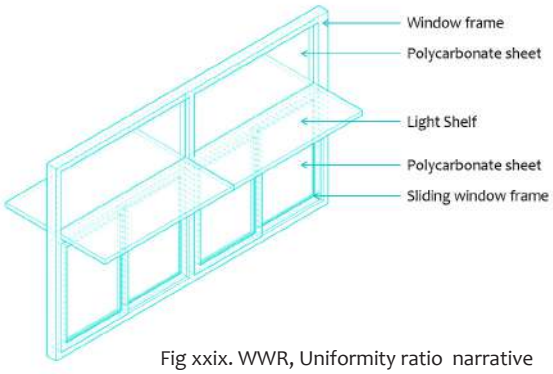



Fig xxix. WWR, Uniformity ratio narrative

The ventilation system comprises of an adaptable cooling system that is often utilised with variable diurnal temperatures and allows the building's occupants to choose the quantity of light and ventilation they desire to enter into the structure.
The manual procedures involved in window operation are as follows:
a) Both casement and sliding windows are manually operated
b) BLDC fans in the building are a switch-operated systems and occupants have the option of speed regulation.
c) light switches are operated by manual control
Instruction for routine inspection and maintenance is that the reflective coating must be cleaned. During the monsoon season we might have to repaint to maintain the efficiency of the light shelf.

The following are the steps that can be taken during emergency situations to manage energy systems effectively:
a) in case of critical conditions, only the important loads are considered given the sunshine hours reduced, and only four days of battery backup is taken into considerations, so the building's critical functions, such as the SDMA office, will be maintained, as will emergency lights and adequate ventilation for the refugees.

## 9.12 INNOVATION

**Power calculation for Prayer Wheels**

We assume that the prayer wheel is rotated by 20 rpm(rotations per minute). To get a rotation of 720 rpm on the dynamo, we use gears that have 1440 and 40 teeth meshed together.

Calculations-
720/20=36 (final rpm/ initial rpm)
Gear 2=40 teeth
Gear 1=40*36=1440 teeth

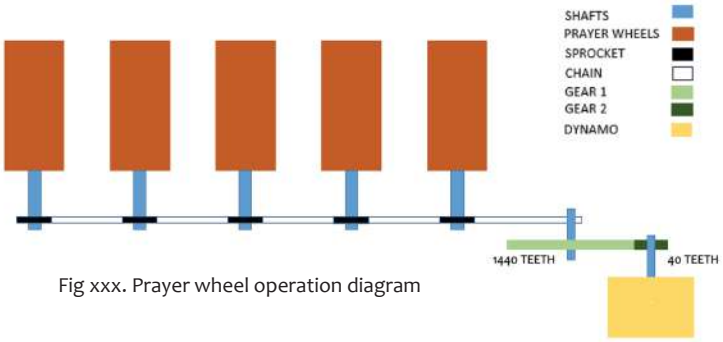



Fig xxx. Prayer wheel operation diagram

**Costing for the prayer wheel**

Number of prayer wheels purchased- 118
Cost of each Prayer wheel- 2000 rupees
Cost of each sprocket- 300 rupees
Cost of chain- 5000 rupees
Cost of gears- 12000 rupees
Cost of dynamo- 7000 rupees

Total cost of the setup = 295400 rupees

**Hardware List**

| S No. | Innovation | Hardware | Brand | Dimensions | |
|---|---|---|---|---|---|
| 1. | The Refuge Rest | 180° Backrest Hinge | Global Furniture Components (GFC 030) | 305mm * 36mm*6mm thk |  |
| 2. | The Serenity Chair | 180° Self-Locking Hinge | Enenes | 700mm*550mm*20mm thk |  |

Table 21 Hardware list

## 9.12 RESILIENCE

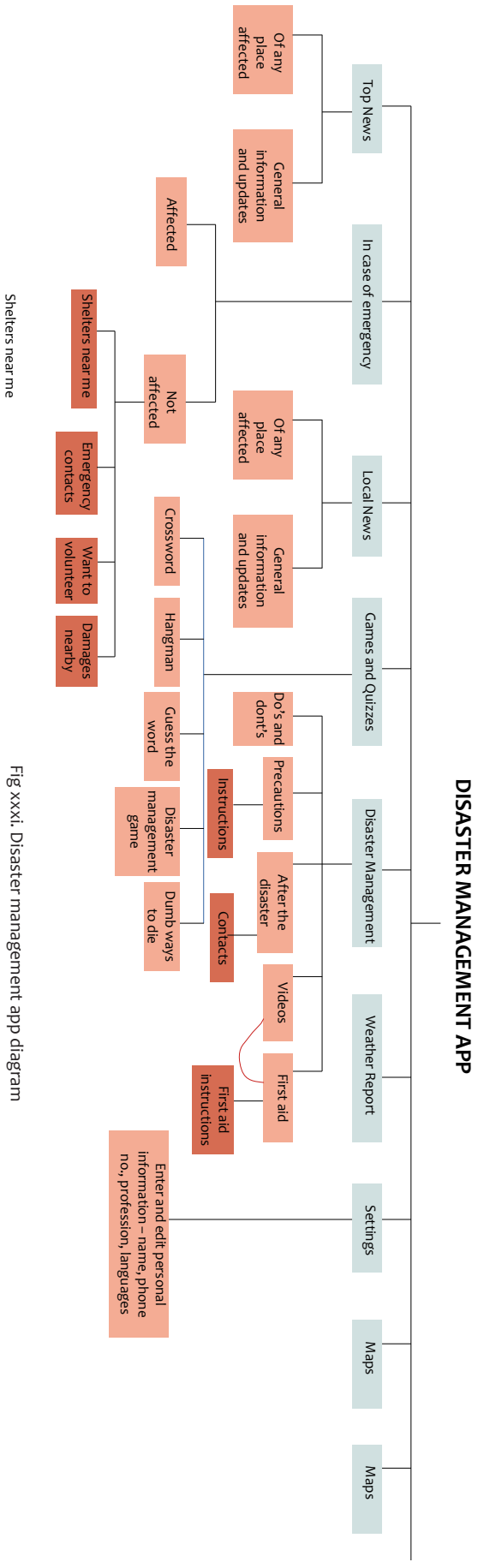
| Food items (ingredients) | Average amount needed per person per day | Amount needed per person for 4 days | Amount needed to feed a population of 320 for 4 days |
|---|---|---|---|
| Maize, rice | 400g | 1600g | 512kg |
| Legumes | 60g | 240g | 76.8kg |
| Vit. A fortified oil | 25g | 100g | 32kg |
| Fortified blended foods | 50g | 200g | 64kg |
| Salt | 15g | 60g | 19.2kg |
| Sugar | 15g | 60g | 19.2kg |

Nutritional value per person- Energy- 2100 calories, Protein- 58g, Fat- 43g
Table showing the amount of food needed to feed a population of 320 for 4 days

| Food items (ingredients) | Average amount needed per person per day | Amount needed per person for 4 days | Amount needed to feed a population of 530 for 4 days |
|---|---|---|---|
| Maize, rice | 400g | 1600g | 848kg |
| Legumes | 60g | 240g | 127.2kg |
| Vit. A fortified oil | 25g | 100g | 53kg |
| Fortified blended foods | 50g | 200g | 106kg |
| Salt | 15g | 60g | 31.8 |
| Sugar | 15g | 60g | 31.8 |

Nutritional value per person- Energy- 2100 calories, Protein- 58g, Fat- 43g
Table showing the amount of food needed to feed a population of 530 for 4 days

## 9.13 VALUE PROPOSITION




Shelters near me

Fig xxxi. Disaster management app diagram

## 9.14. Letter of confirmation from project partner

GOVERNMENT OF ARUNACHAL PRADESH
OFFICE OF THE SENIOR ARCHITECT PWD AP
ITANAGAR
sapwdapi@gmail.com

NO. SA/E-1 ( GEN ) /2022-23/ 3029 DATED ITANAGAR AUGUST 30, 2022

To
The Director
Solar Decathlon India

Dear Sir

This is to inform you that our organisation, PWD AP has provided information about our community Resilience Shelter project to the participating team led by RV College of Architecture, so that their team 'EnCircle' may use this information for their Solar Decathlon India 2022-23 competition entry.

As a project partner to this team for Solar Decathlon India 2022-23 competition, we are interested in seeing the Net – Zero – Energy, Net – Zero – water, Resilient and Affordable solutions that this student team proposes and the innovations that result from this.

We have no issues with our organisation logo being displayed on the Solar Decathlon India contest, recognising us as one of the project partner for the 2022-23 competition

DAWA TSERING
Senior Architect PWD AP
ITANAGAR

30/08/22

Office of the Senior Architect, PWD
Date.....
Mowb-II, Itanagar (A.P.)

FIDUCIA AI (INDIA) PRIVATE LIMITED
**Phone:** +91-6302395390 ***Web:*** *www.fiduciaai.com*

**Date: 18-Feb-2023**

## ***Industry Partner Confirmation Letter***

To,

The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organization, **Fiducia AI India Private Limited**, is collaborating with the participating team led by **R.V. College of Architecture** on a Community Resilience Shelter Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration was to provide technical assistance in software development as part of their project.
`

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

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

With warm regards,

**Nipun Goel**
**CTO & MD**
Fiducia AI India Private Limited
nipun.goel@fiduciaai.com
+91-6302395390