Solar Decathlon India

RV College of Architecture

Final Design Report

April 2023

Division: Educational Building

Project EKĀGRA
Team: **GREEN COLLARS**
Project Partner: **GYANDEEP FOUNDATIONS**

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4.1. ABBREVIATIONS

GHG - Green House Gas

AEC – Architecture Engineering & Construction

EPI - Energy Performance Index

lcpd - liters per capita per person per day

WWR - window wall ratio

WPI - water performance index

EC - Embodied carbon

EE – Embodied Energy

OPEX - Operational Expenditure

CAPEX - Capital Expenditure

AAC - Autoclave aerated cement

RCC -Reinforced cement concrete

SHGC - Solar Heat gain coefficient

VLT- Visual Light Transmission

UDI - Useful Daylight Index

HVAC - Heating Ventilation and Air Conditioning

SOLAR PV - Solar Photovoltaic

AC/DC - Alternating Current / Direct current

CGWB -Central Government Water Board

RWH - Rain Water Harvesting

ASDMA - Assam state disaster management authority

VRV - Variable Refrigerant Volume

DOAS - Dedicated Outside Air System

BMS - Building Management System

COP - Coefficient of Performance

BEE- Bureau of Energy Efficiency

PWSS- Pipeline water supply system

NTPC – National thermal Power Corporation

ICE – Inventory of Carbon and Energy

BSRIA – Building Services Research & Information Association

USGBC – United States Green Building Council

5. EXECUTIVE SUMMARY

With the global GHG emissions raising the global temperature and making climate change a real threat, the future of life, as we know it, on our planet EARTH stands questionable. The AEC sector is responsible for 30% of total global final energy consumption (Source: International Energy Agency). One of the few ways we can attempt to ensure a safe and satisfactory future for the generations to come is by curating current systems to align with sustainable practices while establishing the importance of the same among the youth.

Our school, **EKĀGRA,** DPS (Delhi Public School) in Nagaon aims to accomplish this very goal. The total site area is 77,054 sqm of which we have proposed phase 1 of the project with a **site area of 43,820 sqm**. Located in the warm and humid suburbs of Nagaon, Assam, the school with an **area of 8072 sqm** is proposed to host **1800 students and 200 teachers and staff**, with the possibility of future expansion. The campus, owned by GYANDEEP FOUNDATIONS works on a build-own-operate model and targets to serve students in Nagaon and its neighboring villages.

While designing the school, our team focused on two primary aspects - one, to design a facility that enhances the sharing of knowledge and ensures productive learning in schools, and two, to make the building a net zero energy, water, and carbon built environment.

A key feature was introduced to the proposal - a Research and Design (RnD) block "*The Vision Wonder*", functioning on the idea of '**YOU RUN THE SCHOOL**', which provides students with hands-on learning from a very young age and introduces the concepts of sustainability that the school is designed on. The RnD block is modular in design, allowing the concept to be replicated and scaled to fit other schools in the DPS franchise and beyond.

The standard EPI for base-case institutions in a warm-humid climate is 150 kWh/m2/yr. Our proposal has an **EPI of 26.5 kWh/m2/yr**. The EPI ratio of our proposed case is 0.36 where as the maximum allowed EPI ratio for a super ECBC building is 0.77. Renewable energy generated through Solar PV is **222490 kWh** annually, which is sufficient to fulfill the energy requirements. The water requirement has been reduced to **16 lcpd** which is a 63% reduction from 45 lcpd, the recommended amount in NBC 2016. The site has an annual rainfall of **9720 kL/yr**, this water is used to generate power, by an innovative impulse turbine system that generates energy of **3500 kWh** annually.

The embodied carbon emissions per functional unit of the building are **71.9 kg-CO_2 e** which is 77% lesser than that of the base case. The building functions have been designed to achieve a net-zero waste status by feeding biodegradable wastes (paper, food waste) into a biogas tank and sending non-biodegradable wastes (plastics) to our industry partners for generating building materials.

One of the major challenges was designing the building for the Seismic V Zone. The building has been designed as a resilience shelter, providing energy, water, and food requirements for four days. Furniture has been designed exclusively to be earthquake resilient. Bamboo and jute partition walls have been designed as internal partitions. Bamboo and other materials have been used extensively to promote the usage of local materials, local labor and reduction of material waste, thereby reducing the project cost.

Comfort levels according to IMAC for mixed-mode schools (16% area is air-conditioned space and 84% area is naturally ventilated), have been achieved. Cooling loads on the south side have been controlled through façade treatment and the mental well-being of the occupants has been paid attention to. Excess glare on the east and west sides has been controlled by reducing the WWR and by adding specially designed shading devices.

The building's internal layout is modular and flexible, which provides a dynamic environment to its users and opens up possibilities for expansion and reuse, which again contributes to a circular built environment. The **total cost of the building has been reduced from 307.32 INR Million (base case) to 266.65 INR Million (design case)** by using local materials, optimizing the foundations, energy and water consumption. This is a 12% decrease from the base case. The proposed building has the potential of additional income streams including leasing out the sports facilities as well as the multipurpose hall.

6. RESPONSE TO REVIEWERS' COMMENTS AGAINST DELIVERABLE 3

COMMENT	RESPONSE & REFERENCE
ENERGY PERFORMANCE • Improve on the window glass design case U value. detail out "Equipment optimization", envelope optimization and lighting & loads design implemented in the design case, to achieve the said EPI. • Appropriate energy simulations and analysis, for day lighting, WWR, passive strategies implemented	• The u-value of window glass in the design case has been improved. (Refer Energy Performance pg 18) • Equipment and lighting load optimisation has been detailed. (Refer Appendix pg 54). • Passive strategies implemented have been shown in detail and simulations have been carried out for the same. (Refer Energy Performance pg 16-17)
WATER PERFORMANCE • Clarity on acheiving Net zero water • Add source for all information like yearly stormwater, base case no.s, etc • Add the strategies used to return sufficiently treated wastewater to a public source • The % of water that goes into the Biogas plant is unclear	• More clarity has been added to achieving net zero. (Refer Water Performance pg.21) • Reference has been added for storm water and base case numbers are mentioned in the appendix. (Refer to Appendix pg 12.9, pg.no 60). • We are using all the treated water on site. (Refer Water Performance pg.22) • 2880kgs sludge is going in the biogas plant (Refer Water Balance Chart pg.23)
EMBODIED CARBON • Type of bamboo being used • Clarity on the treatment and hence the carbon footprint of bamboo • Use of bamboo quantitatively • Explain lime plaster availability	• Species : Bambusa Balcooa (Refer pg 25) • The treatment process is detailed, and the EC factors have been mentioned along with the quantities. The disposal of Boric borax solution is also detailed out (Refer pg 25) • Lime plaster is available in Assam along with the required labour (Refer pg 24)
RESILIENCE • Consider energy sufficiency in such times & justify your proposal (solar power) • Alignment with risk assessment, disruptions, design integrations, both quantitatively and qualitatively.	• Energy sufficiency has been achieved by both solar panels and Impulse turbine (Refer pg 29/20) • The recovery plans have been made with quantification and quality analysis along with critical functions of the building (Refer pg 29/27) • Risk assessments, and disruptions have been detailed aaccording to the Assam disaster plan management sources (Refer pg 27-30)
ENGINEERING & OPERATIONS • Explain how electrical systems and plumbing are planned in the building, provide the sizing calculations of these systems • Details on engineering of the layouts of water, lighting, electrical as well, some of which you have shown in the Annexure • Add the BEE star rating for the proposed HVAC systems	• For the electrical system, a detailed layout of one module of the classroom has been worked upon. Electrical systems details and calculations are mentioned (Refer Appendix pg 53) • The plumbing layout and placement of the system on site have been shown and explained in the form of drawings • Further HVAC layout has been provided with the placement of outdoor units on-site and indoor units inside the building. • BEE rating for the proposed HVAC is more than four star(>4 star) • Refer pg 31-34
ARCHITECTURAL DESIGN • A few lines of justification for your design decision, circulation, construction details, engineering systems and services, etc • Mention the type of shading devices used in each orientation. • Show the functionality and efficiency of the building in terms of circulation, servicing and adjacency • Highlight the user experience for the end users through narratives or drawings.	• 74% of the built up area is dedicated to the primary use of the building with only 26% used for circulation and ancillary requirements. • User experience has been shown through a dialogue between two students, highlighting key spaces of the project (Refer pg 37) • The table shows the various shading devices on the building facade (Refer pg 17)

COMMENT	RESPONSE & REFERENCE
AFFORDABILITY • Rework on calculations - seem to be off quite a bit. • Try stitching together payback periods & ROI's to support your CAPEX' • Add the cost implications for your innovations	• Calculations have been checked and corrected in the costing sheet attached separately • The errors in the sheet formulae have been corrected by SDI and the Financing cost and LCC sheets have been connected. • Costing for the innovations has been added, as well as ROI calculations for the same (Refer pg 38) • **Refer D4_EDU_GreenCollars_CostEstimate.xlsx attached**
INNOVATION • Follow the 6 points outlined in the documentation requirements • Is there a market necessity/ problem that you seek to address, need to be answered • Mention things like marketability in addition to this detailed explanation • Structure your narrative around the six points listed in Appendix D	• All the innovations have been detailed following the 6 points mentioned in the documentation requirements. • Each innovation is addressing a different problem that is frequently faced in that climatic and geographic region or generally in schools and has been listed separately for each innovation. • The marketability of each product has been added to the detailed explanation. • Please refer pg.39 onwards for the innovation details.
HEALTH & WELL BEING • How many occupancy hours are comfortable with natural ventilation & what is the comfortable indoor temperature • Add simulations • What are the design measures to ensure proper indoor air quality & comfort • What are the decibel levels it can curtail & how much can it absorb -partition walls • Provide references for indoor air quality strategies • Show the thermal comfort standards mentioned in the pre-design analysis of your report.	• The percentage of comfortable operational hours as well as the comfortable indoor temperature value have been mentioned in the thermal comfort analysis. (Refer pg 42) • All the strategies have been validated through simulations. (Refer pg 42-44) • Strategies to ensure indoor air quality and comfort have been detailed further and references have been mentioned • Decibel levels and sound absorption values for the acoustic partition walls have been mentioned too. (Refer pg 43) • The standard that was chosen for thermal comfort mentioned in the pre-design analysis has been mentioned here as well. (Refer pg 42)
VALUE PROPOSITION • Compelling narrative to the Project Partner, not the end user is required	• The narrative for the project partner was mentioned in D3, but it was not clear enough. We have refined this and added the narrative for the project partner as well as the end-user (Refer pg 45)

7. TEAM INTRODUCTION

7.a.1 Team Name

Green Collars

7.a.2 Institution(s) Name

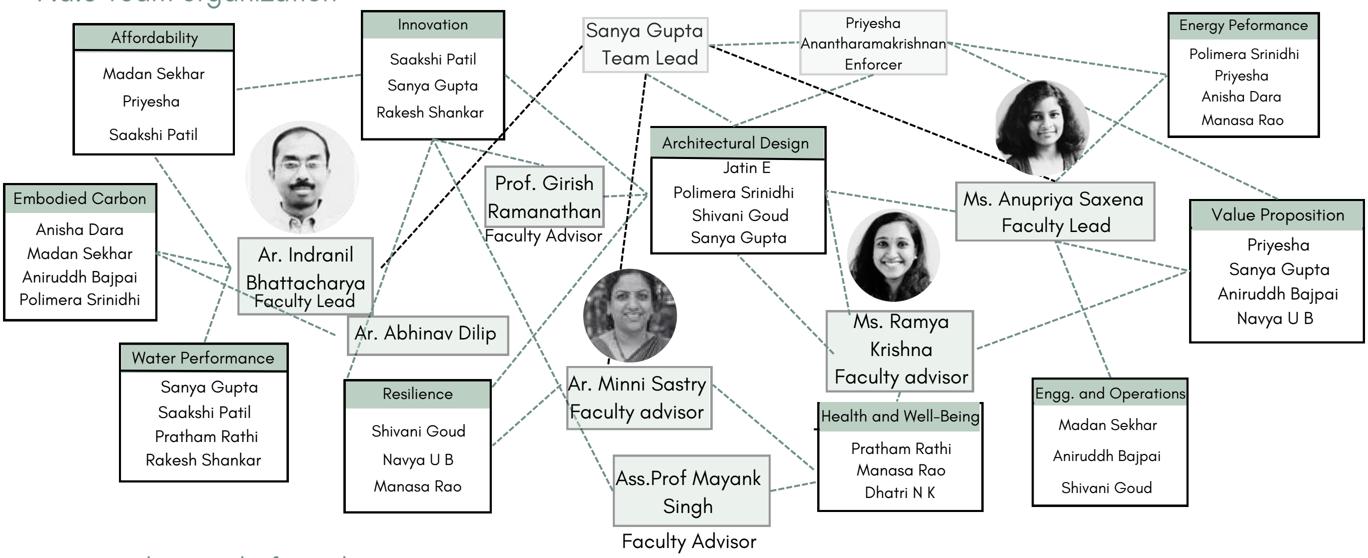
R V College of Architecture, R V College of Engineering, R V University

7.a.3 Division

Educational Building

7.a.4 Team Members

7.a.5 Team organization



7.a.6 Background of Lead Institute

R.V. College of Architecture (RVCA), was established in 1992, as the Department of Architecture in R.V. College of Engineering (RVCE), Bengaluru. In 2014 they shifted to a new campus and function independently, nurturing academics, profession and research for a sustainable contemporary society. The institute offers degree programs for Bachelors and Masters in Architecture.

7.a.7 Industry partners

Zerund bricks is known as a Plastic Embedded Lightweight Brick. It is a patented lightweight brick of Zerund Manufacturing Pvt. Ltd. Industrial production of this building material started in the year 2018 in Guwahati, India. Energy saving and pollution free techniques are used in its production.

ZERUND

CGBMT (Centre for Green Building and Technology)is an Indian NGO working to promote and provide environment-friendly, low-energy and cost effective solutions for sustainable living through advocacy, skill development, education and project execution. CGBMT's goal is to promote a sustainable way of living, working in the sustainable building centre for 15 years in various fields of construction and design.

7.b. Design management process

AUG'22

Project Introduction
- Understanding of net-zero building requirements
- Conducting meetings to understand client requirements
- Allocation and division of team members based on interest
- Selection of the best site out of the three options

SEPT

Pre-Design Requisities
- Conducting case studies
- Site analysis - receiving drawings and reports from client, visiting the site, shortlisting of strategies based on climate and context
- Detailed building area programme and zoning based on client requirement
- Preliminary estimation on base case and budget case

OCT

Design Ideation
- Conceptualizing the design ideas based on SLMs and webinars by the design team
- Identification of relevant codes to base the design strategy
- Aiming to achieve net-zero building as well as holistic development and learning of the students

NOV

Design Implementation
- Incorporating net-zero strategies and simulating the same to check; choosing the best strategy based on simulations
- Working on wind thermal, daylight simulation in order to achieve the comfort conditions

DEC

Integration of systems
- Discussing with the industry partner about the various building systems
- Creating a material passport, identifying the most efficient and optimal material for the design

JAN'23

Design Optimization
- Scalability, methods and market analysis
- Integration of rain water harvesting systems

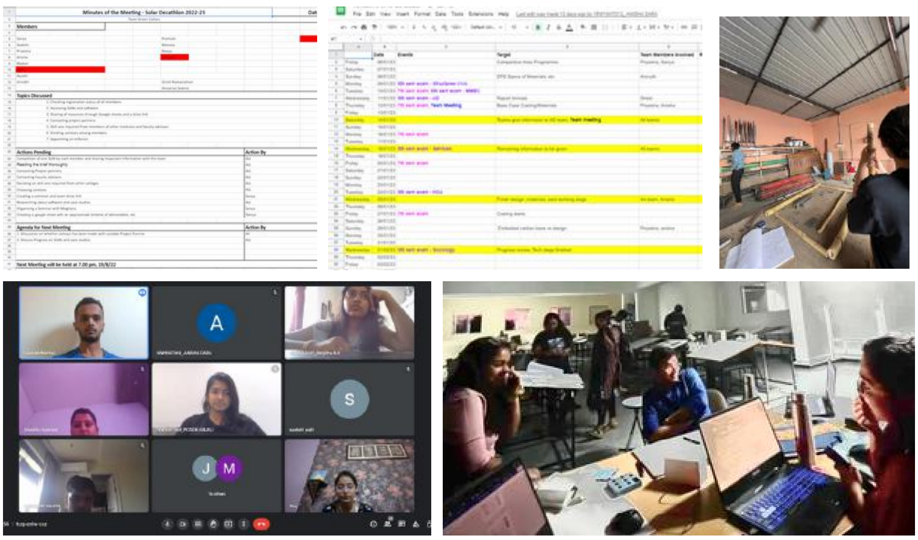
FEB'23

Refining
- Back and forth process of design innovation and research
- Calculating the detail budget analysis of design and base case

MAR, APR'23

Improvements
- Reviewing the feedback
- Learning about the local materials in detail
- Continuous meetings and discussions with the team
- Development of prototype

Figure 7.b.a Design management process



Software Used

ClimateStudio, DesignBuilder, Rhinoceros, Excel, AUTOCAD, Ps, Revit, LUMION, SketchUp, Ansys

Figure 7.b.b Images of design process

Study archival
Conducting Workshops and discussions

8. PROJECT BACKGROUND

8.a. Project Name

Project **EKĀGRA** -Delhi Public School, Nagaon

8.b. Project Partner

Gyandeep Foundations - Mr. Ashwini Chhawchharia, Vice President

8.c. Brief description of the project

The client proposes to provide quality education for the community at large. Phase 1 involves the School and associated Facilities - Utilities (which we are designing) being strategically planned at one end of the 77,000 sqm site. Some features of the area are:

- The Kolong River, a tributary of the Brahmaputra River, which flows through Nagaon.
- Major crops grown: Paddy, potato, mustard, jute, sugarcane, wheat and other vegetables
- Major occupations: Agriculture, horticulture, live-stock rearing, poultry, fishery

Scope of the Project: Designing a school that facilitates a hands-on learning approach. Incorporating a unique Research and Design lab in the school for students to learn and further their knowledge on sustainability which can become a unique prototype for the DPS franchise .

Location: Deodhar, Nagaon , Assam
Latitude: 26°18'14"N
Longitude: 92°40'51"E
Climate Zone: Warm and Humid
Market: Guwahati to Nagaon - 120 Km
Status of the Project: Finishing stage

Hours of Operation : 9:00-16:00 (for students) (Monday - Friday , Saturday 8:00 - 13:00)
8:00-17:00 (for staff) (Monday - Friday, Saturday 8:00 - 14:00)

Socio-Economic Background: The distribution of the work forces in the district as per the Census 2001: Out of 727,641 workers 641,273 persons are engaged in the rural sector and 86,368 are in the urban sector.

Profile of Users: Currently planned for 1800 students and 200 staff members. Age group 4 - 18 years

Figure 8.c.a Context plan

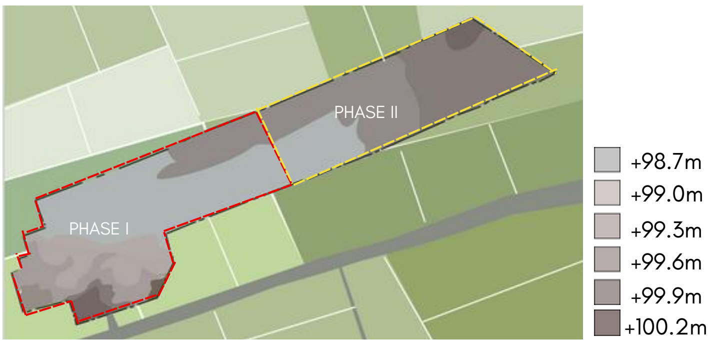


Figure 8.c.b Contour Plan

PHASE I   PHASE II

	SITE AREA	BUILT UP AREA	GROUND COVERAGE	SETBACKS	BUILDING HEIGHT
Assam standards (Permissible)		43820 sqm (FAR =1)*	15340 sqm (35%)*		30 m*
Proposed Case	Site Area for Phase 1 - 43,820 sqm Total Site Area - 77000 sqm	8072 sqm	3340 sqm (detailed explanation given in the Building Area Programme on page)	9 m on all sides	8.1 m

Table 8.c.1 Area Details

For a detailed area program refers to appendix 12.3, appendix table 1, page no.50

**Source: Government of Assam - Orders by the Governor for Urban Development*

Figure 8.c.c Site images as of 2nd Feb '23

On-site renewable energy generation:

- The total energy generation through solar panels will be 222400 kWh annually as shown in page 16. EPI of our proposed case is 26.5 with an EPI ratio of 0.36.
- The amount of harvested water we will receive is 9720 KL/yr , which will be used in a impulse turbine system to generate energy as shown on page 22
- The energy generated from the impulse turbine system is 3500 kWh annually detailed on page no. 28, refer appendix pg 72 for further calculations.
- Biogas generated from biomass for cooking is 6075 kg annually as shown on page 27

SWOT ANALYSIS

STRENGTHS

- A multidisciplinary team has helped in wind and thermal simulation
- The team is well-versed in software and simulation
- The team consists of 12 architects who have acquired the knowledge on various building systems , 1 mechanical engineer having the knowledge for mechanics and 1 spatial designer having the knowledge on interior spatial arrangements
- All the team members hold good team spirit with the ability to work as a group efficiently

WEAKNESSES

- Lack of structural engineer in our team hence, collaborated with structural engineer professor from the institute and solved the design problems
- Lack of knowledge of bamboo hence, collaborated with Ar. Neelam Manjunath
- Unable to visit the site, hence collaborated with Ar. Abhinav Dilip

OPPORTUNITIES

- Local availability of bamboo
- Located on NH37 - Easy transportation and accessibility to site
- Abundant rainfall - Electricity generation through water is achievable
- Access to Paddy fields, jute mills and bamboo
- Fairly uniform climate
- 2000 occupants
- Due to large site area, the scope of energy generation(solar) is more.
- Rice husk, jute, occupancy - Biogas
- Incorporating local materials and labor, in turn raising the economy

THREATS

- Earthquake zone site
- High water table
- Flooding
- High Humidity

Figure 8.c.d SWOT Analysis

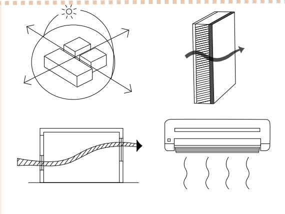
8.e. Special requirements of the project partner

- The building must have a use as a resilience center for the local population
- Achieving at least a 3 star GRIHA rating for new construction
- Universal accessibility of the project
- Self-occupied building

9. GOALS AND STRATEGIES

ENERGY

- To achieve a net-zero energy building with a target EPI of 30 kWh/sqm/year (GRIHA benchmark = 90 kWh/sqm/yr) (energy generated = 222400 kWh; **Achieved EPI = 26.5 kWh/sqm/year**)
- Target reduction of the solar heat gain by the envelope by 50 %. (**Achieved - 60%**)



WATER

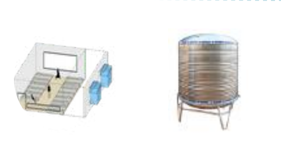
- To design a Net-zero water building. **(Achieved)**
- To have zero water discharge. **(Achieved)**
- To treat 100% wastewater on-site and reuse 100% treated water on-site. (**Achieved**)
- Target Water Performance Index (WPI) < 45 Lpd (Base value -from NBC). (**Achieved WPI = 16.4 Lpd**)
- Ensuring self-sufficiency through storing 11,000 lts of water for daily consumption which provides resilience for **4 days** during a disaster

CARBON

- Reducing transport-related emissions by sourcing materials locally **(within a 160km radius)**
- Target reduction of embodied carbon emissions to be 50% less than the base case; (**Achieved reduction of EC = 77%**)
- The total embodied carbon emissions per functional unit will be less than 120 kg-CO_2e; (**Achieved = 70.7 kg-CO_2e**)

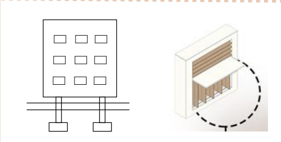
RESILIENCE

- To provide energy backup that can sustain the facility for a period of 4 days (**Achieved**) during a disaster
- Creating a multi-resilience structure(**Achieved**)
- Food resilience **(Achieved)**



ENGINEERING & OPERATIONS

- Reduce unwanted energy wastage during the operation of building. **(Achieved)**
- Material selection based on ease of availability, maintenance and operation.
- To achieve Net-Zero waste. **(Achieved)**
- Provide efficient structural system. **(Achieved)**



ARCHITECTURAL DESIGN

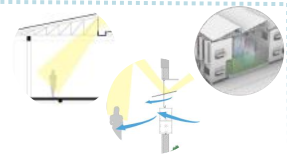
- Providing opportunity for students to learn in an open environment, evoke awareness about sustainability and energy efficiency of the campus
- Enhancing building, and user efficiency and comfort, through design

INNOVATION

- To design a device to generate energy to utilize the large amount of rainfall on our site with low OPEX. (**Achieved- HYDRAWATT Impulse Turbine**)
- Utilize locally available materials to make sustainable acoustic panels and internal movable partitions. (**Achieved**)
- Design furniture to facilitate student safety in earthquakes. (**Achieved- Safety Prism**)

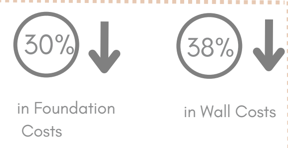
HEALTH & WELL-BEING

- Achieving 100% comfortable operational hours. **(Achieved)**
- Target 100% day-lit building during ideal weather conditions. **(Achieved: 75% of operational hours)**
- Ensuring good indoor air quality and mental-wellbeing of the students to increase their productivity. **(Achieved)**



FINANCIAL AND MARKETING

- Aiming at OPEX 10% lower than the base case. We have achieved a reduction of **30% in the OPEX** and a **12% decrease in CAPEX.**
- To promote the learning approach by the generation of energy.
- Incorporating a unique Research and Design lab in the school for students to learn.



10. DESIGN DOCUMENTATION
10.1 ENERGY PERFORMANCE

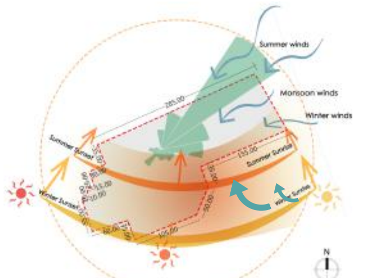


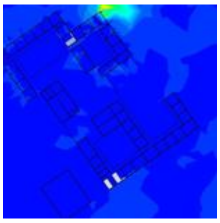
Figure 10.1.a Sun path Diagram

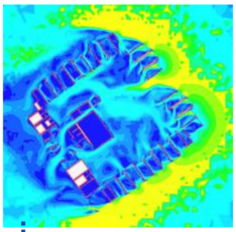
DESIGN APPROACH

The Building is placed on a higher elevation of the site to avoid water logging & flooding. The main intent was to create an adaptive, interactive playful & comfortable design for the users, by incorporating passive design strategies to achieve a sustainable design

DESIGN ITERATIONS

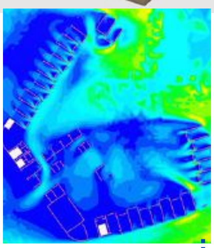
Flow of wind is obstructed by the building facade

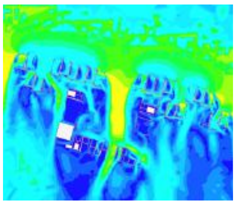




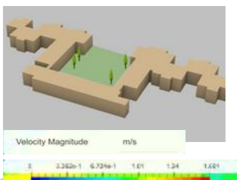
Funnel effect created to capture wind flow, but shows restricted flow at east and west facades

Classroom wings are angled to increase funnel effect, but shows negative effect on southern side



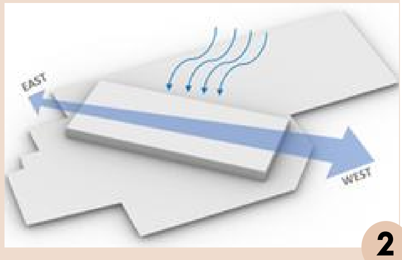


Final iteration shows classrooms at the northern side to maximize wind flow and conditioned spaces at the southern end



1

Building follows setbacks and permissible built up area. Structure built on a porous plinth



*Source: Government of Assam – Orders by the Governor for Urban Development

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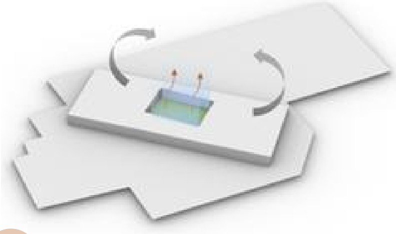
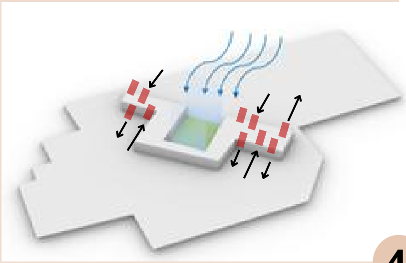


Reducing facade area on east and west enhanced with courtyards and jali walls. Maximizing openings on north for wind & light allowance.

3

Staggering of classes and the large central courtyard is done to maximize wind movement and helps in self shading of the classes.



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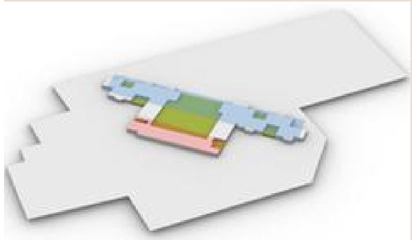
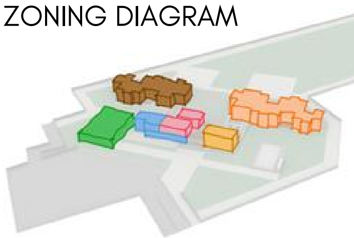
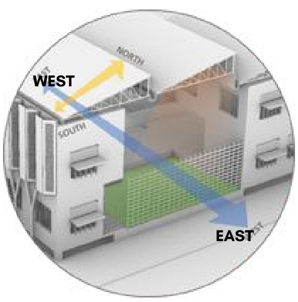


The design constitutes classrooms at the northern side to reduce the cooling loads and maximize daylighting of building

ZONING DIAGRAM

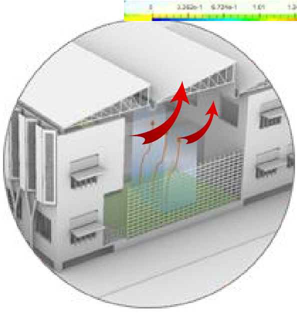


- Admin (mixed mode ventilated)
- R&D block and Labs (mixed mode ventilated)
- Library (naturally ventilated)
- MPH (mixed mode ventilated)
- High and Middle school (naturally ventilated)
- Pre and Junior school (naturally ventilated)



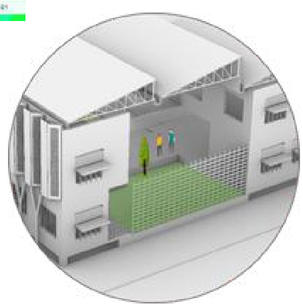
ORIENTATION

East-West orientation increases ventilation and day light access



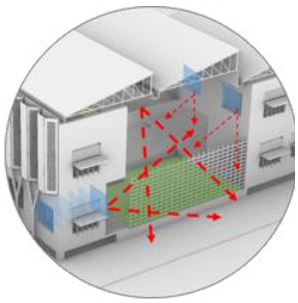
CROSS VENTILATION

Voids and openings help in effective wind movement throughout the building



COURTYARD

Courtyards in the building, provide natural ventilation to classrooms and corridors



VISUAL INTERACTIVE SPACE

Intermediate break out spaces to increase efficiency in learning

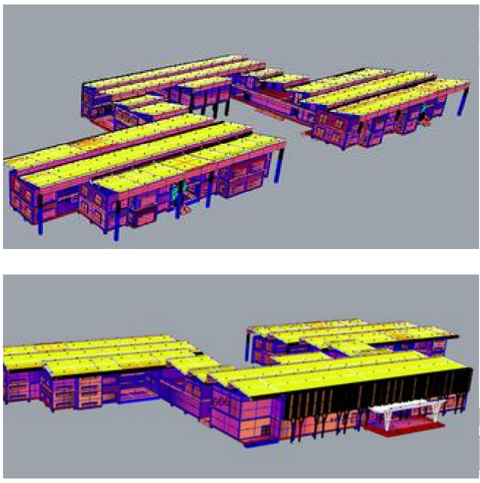


Figure 10.1.b Solar Radiation

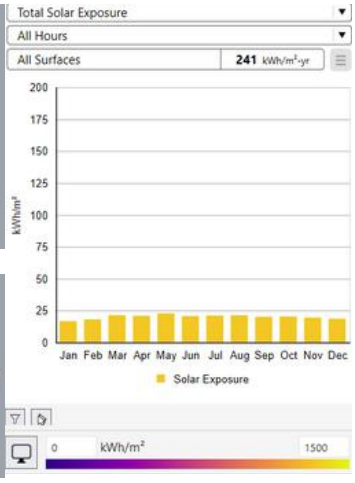


Figure 10.1.c Annual graph showing radiation

Solar radiation for the proposed iteration was observed to be 241 kWh/m2-Year (Software: Climate Studio).
North and west had the lower values varying from 550-750 kWh/m2.

Solar radiation for South and east façade had higher values compared to other two side, values observed were around 100-1200 kWh/m2-Year. Roof of the building had highest surface value of 1750 kWh/m2- Year

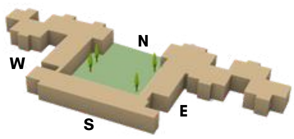


Figure 10.1.d Key plan

Window and shading device design

The window-wall ratio for each wall has been optimized based on the solar radiation simulation, the opening is maximized on the north to let in more natural light and wind (primary wind direction) while optimizing the east and west openings to reduce the excess glare.

On the northern facade, windows on the ground floor and upper floor have been fitted with bamboo louvers which are coated with resin to reflect sunlight into the building, acting as a light shelf. The ceiling is whitewashed to improve reflectivity of light further (0.7-0.8).
The landscaping outside the window also helps in reducing the temperature of the wind entering the spaces and offers better views, thus increasing visual comfort. Appropriate shading devices have also been designed for each facade to reduce glare.

Utilizing the sunlight from the northern side, the first floor is roofed with a north-light truss to optimize the amount of daylight entering the building and improving visual comfort.

WWR Ratios

Facade	WWR
North	40%
South	20%
East	10%
West	8%

Table 10.1.1 Window-wall ratios

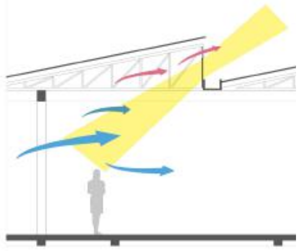


Figure 10.1.e Section through north-light truss

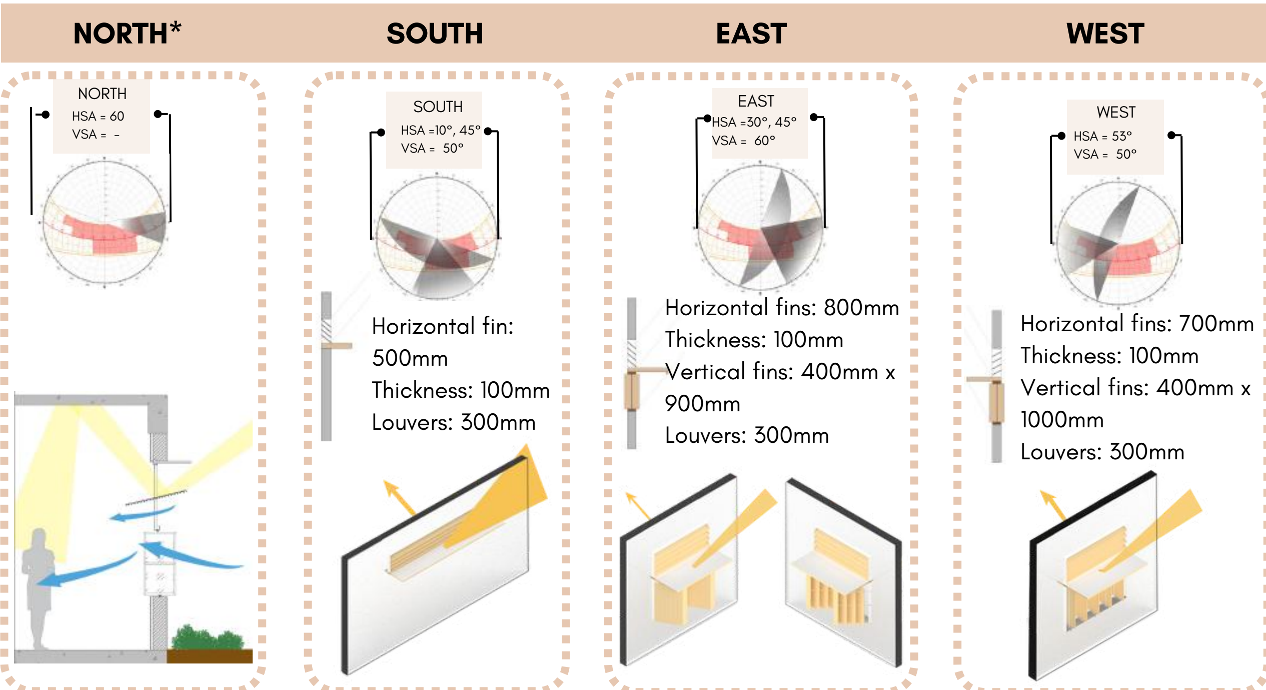


Figure 10.1.f Shading devices designed for each facade according to the shading angles

*Detailed window section for north window mentioned in engineering and operations , pg. no 32

The shading devices have been designed very flexibly as rotatable louvers which can double as window shutters as well as light shelves.
The bamboo louvers are coated with stabilized clay mixed with rice husk and lime to increase its reflectivity. This also acts as a plaster and protects it from rain and harsh weather.

EAST / WEST

The facade area is reduced on these sides. Courtyards and jali walls with landscaping to reduce harsh sun

SOUTH

Entrance

A module acting as both a shading device and facade to prevent direct harsh sunlight and allow for air movement, reducing the cooling loads for the mixed mode ventilated spaces .

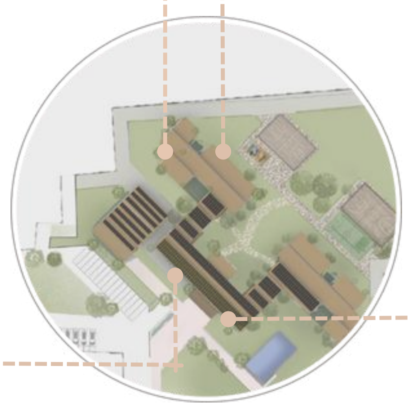
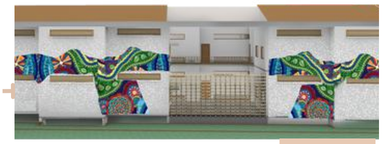


Figure 10.1.g Key plan and building elevations

NORTH

Maximizing the openings for both light and wind to flow into the building



Classrooms

SOUTH

Mosaic Reused Tiles are used on the façade of the classes by creating vibrant patterns which also helps in reflecting back the harsh sunlight

Energy consumption

	BASE CASE	PROPOSED CASE
	Energy base case	*Detailed energy calculations shown in the appendix pg 54*
Annual power consumption	**522500 kWh / yr**	**213990 kWh / yr**
Energy Performance Index (EPI)	**73.6 kWh/m2/yr**	**26.5 kWh/m2/yr**

The goal set for energy performance was achieving an EPI of 30 KwH/m2/yr. We have achieved an EPI of **26.5** KwH/m2/yr. The approach to the energy efficiency goal is in two steps. The first step to reduce energy consumption is done using passive strategies, derived from pre-design simulations and a design-oriented approach. Passive strategies used include effective zoning, orientation, use of courtyards and shading devices, and building configuration. The following steps further optimize energy consumption.

Envelope optimisation

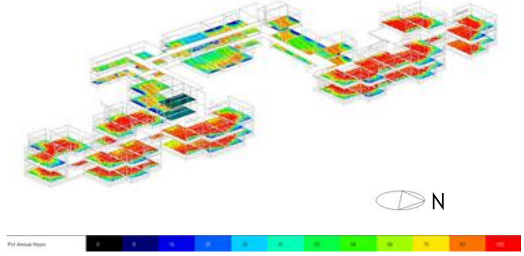
	Walls	Roof	Windows *
Standard Design	19mm plaster + 200mm AAC+ 15mm plaster U value : 0.41 W/m2-K	200 RCC Slab , screed finish U value : 1.51 W/m2-K	Single glazed 4mm clear glass. U value : 3.6 W/m2-K
Proposed Design	OUTSIDE -- • 19mm lime plaster + pigment • 200mm Zerund bricks • 40mm air cavity • 6mm cross laminate bamboo mat boards INDISDE ------- **U value : 0.28**	• OUTSIDE -- • 4mm Bamboo corrugated sheeting • 50mm U tone insulation panel • 50mm air cavity • 4 mm Bamboo corrugated sheeting INSIDE ----------- **U value : 0.28**	SHGC = 0.47 VLT = 59 % OUTSIDE-- • Double glazed window with 6mm solar control glass + 12mm air gap + 6mm clear glass INSIDE ------- **U value : 1.4**

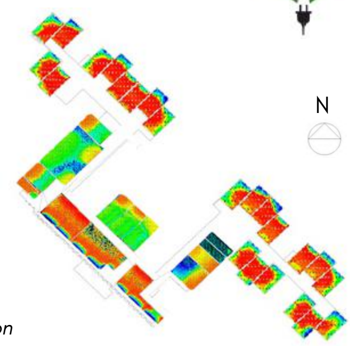
Table 10.1.2 Showing base case vs design case envelope optimization

*Windows are openable. U value proposed is for the glass which is fixed . As we are proposing for natural ventilation, windows are open most of the time. Window design is detailed out in engineering and operations pg no - 33

Daylight optimisation

Availability of daylight is maximised by using strategies like a narrower floor plate, use of light shelves, use of the north light truss and the use of proper window glazing.





Simulations of UDI in classrooms prove that the classrooms are daylit for **75%** of the year which reduces lighting loads.

Figure 10.1.h Showing UDI simulation
Source: Design builder software

Equipment optimisation

Base case	410710 KWh / yr	55% reduction
Design case	184000 KWh / yr	

Detailed calculations shown in the appendix pg 55

Usage of energy-efficient equipment and considering the school schedule as operating hours for the equipment, the equipment load is reduced from the base case. The use of staircases rather than lifts is encouraged through design.

Comfort optimisation

The major part of the heat gain from openings is catered to,by shading and envelope optimization. Heat gain from other factors is reduced by choosing efficient fixtures and maximizing fresh air circulation.

	Standard (Btu/hr)	Design case (Btu/hr)	% reduction
Envelope	379260	150990	60.2%
Equipment	100255	20630	79.4%
Lights	13640	2810	79.4%
Fresh air	94440	24110	74.5%

HVAC Rightsizing

The need for HVAC is completely eliminated for almost 84% of the building area by using passive methods such as orientation optimization, courtyards, self-shading, and the use of shading devices. For the 16% of the building area where HVAC is used, HVAC load is optimized taking into account the u values of the envelope, load of equipment and lighting.

Base case	16505 KWh / yr	% reduction 63%
Design case	6070 KWh / yr	

Detailed calculations shown in the appendix pg 58

Setpoints for HVAC

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Setpoint	27	25	26	26	25	25	26	25	26	26	27	27

Reduction in EPI using energy conservation measures

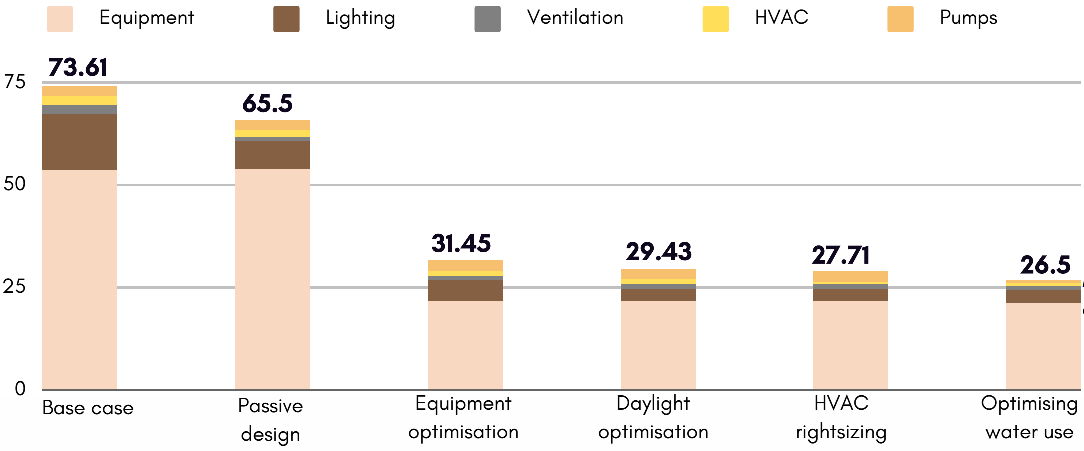


Figure 10.1.j Graph showing EPI reduction

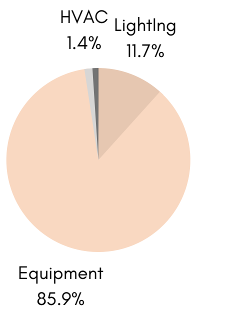


Figure 10.1.i Pie chart showing energy consumption breakup

+ Solar PV = Net +ve
222400 KWh/yr

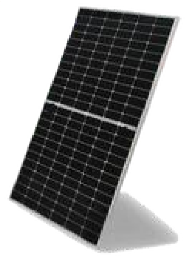
Equipment power density	Lighting power density	EPI Break up		
EPD - 3W/sqm	LPD - 1.5 W/ sqm	Equipment - 21	Lighting - 2.98	Comfort - 2.52

Renewable energy generation

Solar energy generation

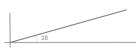
The site receives an average solar irradiance of 5.87 KWh/Sqm/day which gives us good potential for solar energy production. Solar panels are placed on 1550 Sq.m of the roof area ***tilted at an angle of 28 degrees.***

Solar panel module specifications



- LG Solar panel – LG440N2T-E6
- Capacity – 160 Kw
- Size – 2,130mm x 1,042mm x 40mm
- Monocrystalline , Bi-facial
- Module Efficiency [%] – 21.2
- Cell Configuration – 144 Cells (6 x 24)

Area of roof used – 1550 Sq.m.
Tilt angle – 28 degrees



Roof area available for future expansion – 3000 Sq.m
Total extra future generation potential – 417167 Kwh / yr

Total generation – 222400 Kwh/yr

Impulse turbine

Apart from the solar panels, we are using impulse turbines (refer to innovation, pg.40) to generate energy. As a future proposal, play equipment and outdoor gym equipment are also planned which generate energy.

Impulse turbine	Play equipment
3500 KWh / yr	**2.5 KWh / yr**

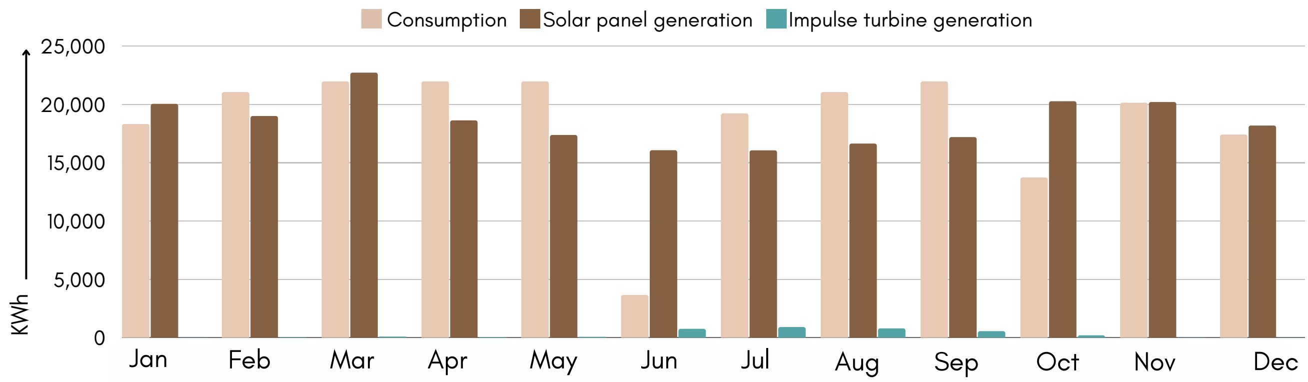
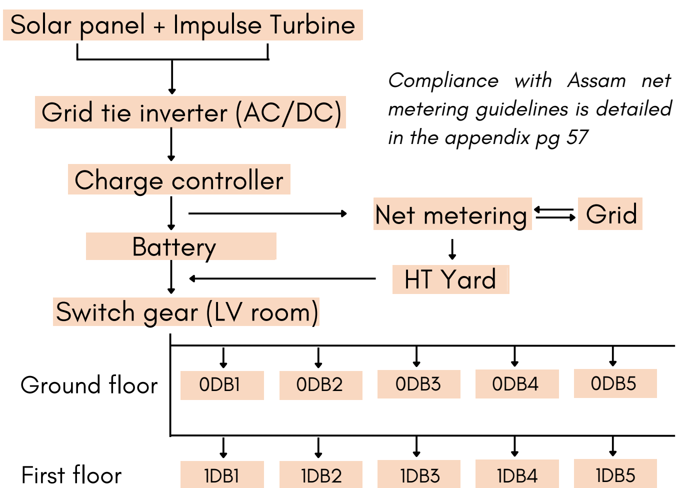


Figure 10.1.k Graph showing annual energy consumption and generation

Grid Interaction System



Compliance with Assam net metering guidelines is detailed in the appendix pg 57

Figure 10.1.m: Energy flow diagram

Battery specifications

Energy that needs to be stored – 5900 KWh
No.of days batteries should suffice – 4
capacity -250Ah , 12V
Model – ILTT 28060
No.of batteries – 20

Figure 10.1.l Solar panel layout

A grid tie inverter is used in the circuit which has anti-islanding protection i.e , this inverter removes our system from the grid when anti-islanding is required.

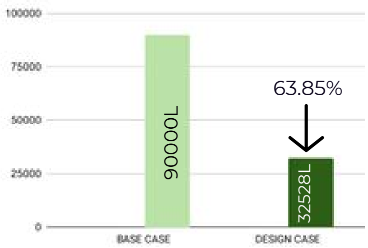
Total Generation		Total Consumption		Net +ve energy
222400KWh/yr	–	213990 KWh/yr	=	8410 KWh/yr

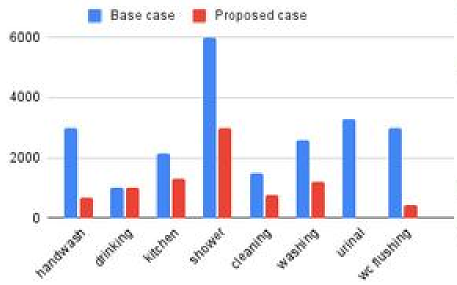
10.2 WATER PERFORMANCE

Minimizing water consumption

The indoor water consumption was brought down to **16.27 lcpd from 45 lcpd (as per NBC) base case** for the normal functioning of the school, We have also achieved a **79% reduction** from the GRIHA base case of **80 lcpd** for institutional buildings by using **efficient fixtures** such as sensor faucets, flush-less urinals, composting wcs front load washing machine, efficient water supply system, and efficient cleaning machines.

Water consumption has been further reduced by using the VRV system for air conditioning which **does not require cooling tower** water demands.





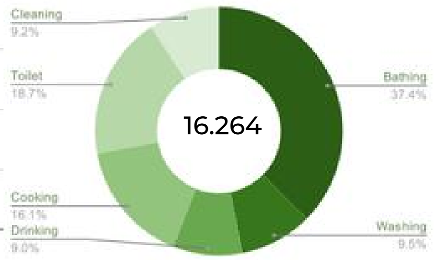


*Figure 10.2.a: Base case vs design case water consumption per day during normal scenario for **2000** people as per NBC*

Figure 10.2.b: Total reduced water demand per day per person

Image of the water fixture					
Water fixture	Sensor faucet	Health faucet	posting foam flush	Waterless Urinal	Kitchen faucet
Baseline water usage LPM (1 BAR PRESSURE)	4.31	8	6	2.2	8
Benchmark water usage LPM (1 BAR PRESSURE)	1.8	4	0.28	0	6
Cost (INR)	5500	1725	33295	5900	2500
Company	Jaguar	Jaguar	clivus multrum	hindware	Jaguar

Table 10.2.1: Showing efficient water fixtures

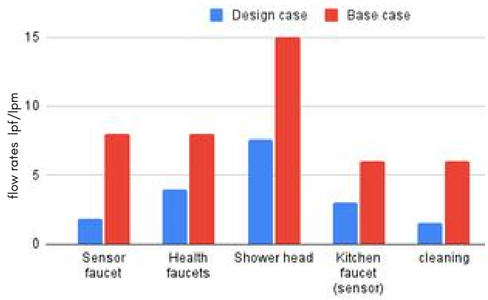


Figure 10.2.c: Base vs Design case flow rate comparison

For further calculations refer to appendix 12.9 , table 15,16,17, page no. 60

Reduced usage would also depend on the habits of the students using the space, which we hope to enhance with the help of interactive visual displays installed throughout the building. The displays would make the students aware of water consumption and encourage them to not waste or overconsume water, resulting in reduced usage.

For further understanding refer to appendix 12.2 ,pg no. - 48

During construction

Proposed best practices

- Use of Zerund bricks for walls that do not require curing
- No internal plastering of the walls saves on the 14-day curing period for plastering as compared to the base case.
- Water reducing admixtures are used
- Use of bamboo truss system for the first-floor slab as compared to base case rcc slab
- MPH built of bamboo saves a lot of water during construction as compared to the RCC base case, treatment water of bamboo is being reused for the foundation
- Use of collected rainwater in the sedimentation tank for construction purposes saves freshwater demand.

Outdoor water use reduction

We have reduced the outdoor water demand for irrigation to 3kL from the base case demand of 10.2kL per annum. This amounts to a reduction of irrigation water demand by 70.52%. The strategies used for this reduction include the use of efficient irrigation systems like drip irrigation and sprinklers, planting only native trees and plants to avoid unnecessary demand for water as much as possible.

The main source of water is Treated Rainwater, and treated wastewater. The average annual rainfall is **1541mm** as per CGWB. According to the climate change data, there is an increase in the precipitation in this region, therefore providing us with surplus rainwater which is stored on-site, making it a **net zero water building** without relying on municipal supply. The treated water is further used for landscaping and flushing . The provision is given for the nearest municipal supply source no. 218 in Deodhar Gaon, Sadar, PWSS

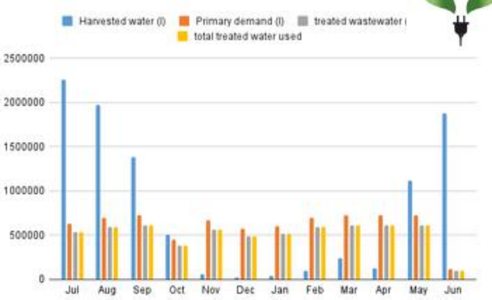


Figure 10.2.d: Generation and consumption

For further calculations refer to appendix 12.9 , table 18, page no. 60

Months	Rainfall (mm)	Effective rain (mm)	Harvested rainwater (l
July	570	565	2257175
August	500	495	1977525
September	352	347	1386265
October	132	127	507365
November	20	15	59925
December	11	6	23970
January	16	11	43945
February	30	25	99875
March	65	60	239700
April	38	33	131835
May	285	280	1118600
June	475	470	1877650
total			9723830
total in Kl			9720

Table 10.2.2: Harvested water

Water harvesting Sources	Area	Runoff coeff
Roof Surfaces	4700	0.85
Hardscape areas	0	0.75
Softscape areas	0	0.3
Effective catchment area	**3995**	

Table 10.2.3: Catchment area

Water consumption point	Quantity	Liters/day
Occupants : {People x l/person}	2000	15.14
Irrigation (max) : {m2 x l/m2}	137500	1.7
Cooling tower (max) : {Ton x l/Ton}	0	0

Table 10.2.4: Water consumption

- 100% of occupants' demand is met by RWH.
- 100% of on-site demand is catered by filtered grey and black water used in flushing and irrigation including organic farming and bamboo plantation.
- 100% on-site water is treated

The catchment area on the roof receives rainwater. This water goes through a rainwater harvesting filter which automatically flushes out dirt and debris. The harvested water is stored in storage tanks for immediate usage. This water is used in drinking fountains, kitchen sinks, and washbasins. Stormwater falling on the ground is taken through bioswales and takes its natural course of infiltration.

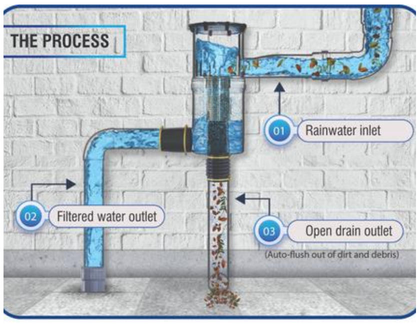


Figure 10.2.f: fl- 500 rainy filtration system

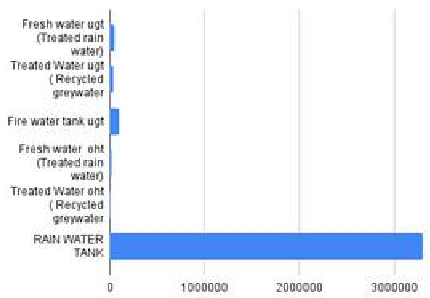


Figure 10.2.e: Tank sizing

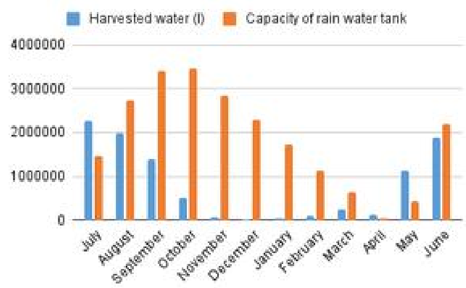


Figure 10.2.f: Rain water storage capacity

For further calculations refer to appendix 12.9 , table 22, page no. 61

Resilience in water supply

In an event of water supply failure, the building has enough storage of water to manage the essential services. The building will have enough water for all its needs for 4 days. The daily demand of the building is met through filtered rainwater and recycled water. The total freshwater requirement for a day is 32530L. We have installed a fire water tank of capacity 210KL. The over flow of which goes to 1.5 day fresh water UGT and further to 0.5 day fresh water OHT.

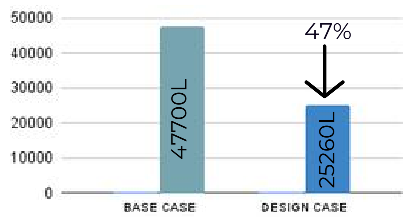


*Figure 10.2.g: Base case vs design case water consumption per day during disaster times for **500** people*

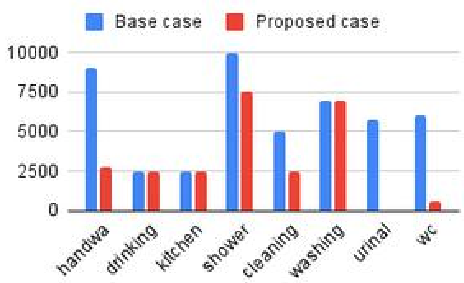


Figure 10.2.h: Occupants activity

With the usage of efficient water fixtures the water consumption has been brought down from **95.5lpd to 50.5lpd** during disasters.

For further calculation refer appendix table 19,20,21 ,pg . no 61

Month	Days in month	Generated black water(l)	Generated Grey water(l)	total generated waste water(l)	treated wastewater (L)	Irrigation seasonal factor (%)	Irrigation demand(l)	irrigation demands for organic farming and bamboo plantation(l)	flushing demand(l)	total treated water used	Cooling tower water demand (l)
Jul	21	279787	356093	635880	540498	0.2	98175	433363	8960	540498	0
Aug	23	306434	390006	696440	591974	0.2	107525	432929	51520	591974	0
Sep	24	319757	406963	726720	617712	0.2	112200	451752	53760	617712	0
Oct	15	199848	254352	454200	386070	0.5	175312.5	177158	33600	386070	0
Nov	22	293110	373050	666160	566236	0.5	257125	259831	49280	566236	0
Dec	19	253141	322179	575320	489022	0.5	222062.5	224400	42560	489022	0
Jan	20	266464	339136	605600	514760	1	467500	2460	44800	514760	0
Feb	23	306434	390006	696440	591974	1	537625	2829	51520	591974	0
Mar	24	319757	406963	726720	617712	1	561000	2952	53760	617712	0
Apr	24	319757	406963	726720	617712	1	561000	2952	53760	617712	0
May	24	319757	406963	726720	617712	0.5	280500	283452	53760	617712	0
Jun	4	53293	67827	121120	102952	0.5	46750	9162	47040	102952	0
total	243	3237538	4120502	7358040	6254334		3426775	2283239	544320	6254334	
total in KL		3240	4120	7360	6250		3420	2285	545	6250	0

Table 10.2.5: Treated water generation and consumption

ECO STP – It is an eco-friendly sewage treatment system that uses anaerobic bacteria. It requires zero power, zero chemicals and produces zero odor. It has lower maintenance as compared to a regular STP.

Treated waste water = 6250 kl /annum with an efficiency of 85%

total Irrigation demand = 6250kl/annum

ECOSTP WASTE WATER → **RUMEN DIGESTOR FILTER(STG 1)** → **RUMEN DIGESTOR FILTER(STG 2)** → **RUMEN DIGESTOR FILTER(STG 3)** → **PLANT BIO FILTER (STG 4)** → **TREATED WATER TANK**

Water balancing diagram

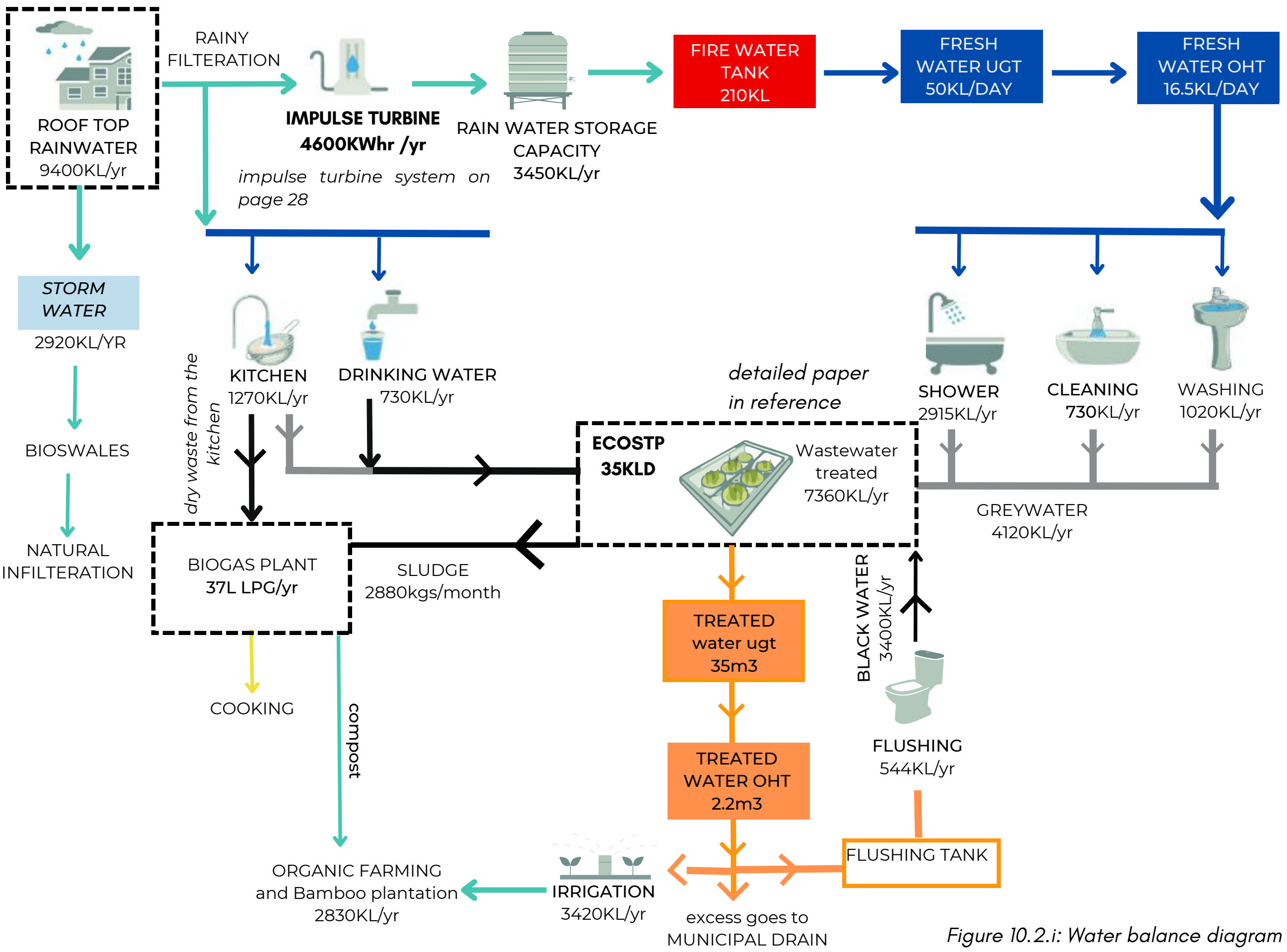
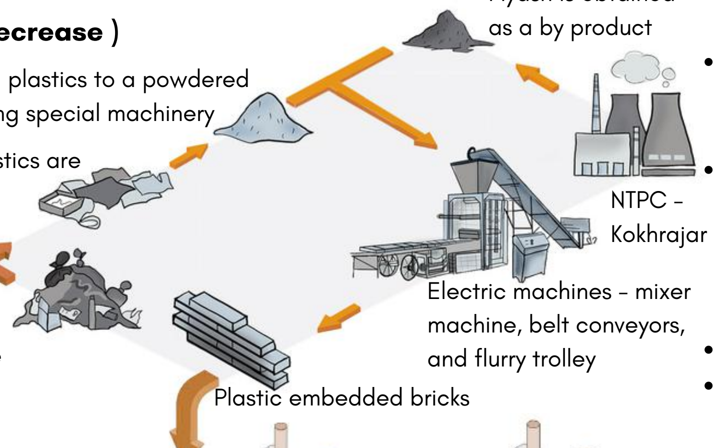


Figure 10.2.i: Water balance diagram

Harvested and generated		Consumed by the people and the landscape		
Rainwater harvested 9400KL/annum +	Treated wastewater used 6250KL/annum	− Fresh Water consumed 9400KL/annum +	Treated water used 6250KL/annum	= 0 Net zero water achieved

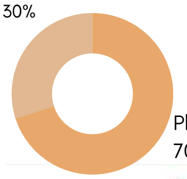
10.3 EMBODIED CARBON

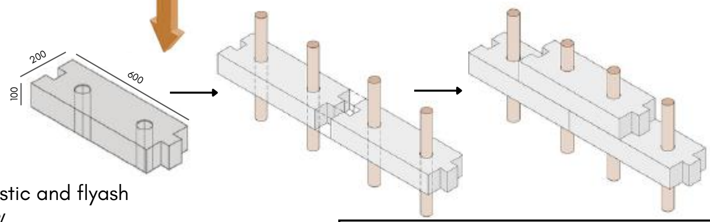
Walls (124% decrease)

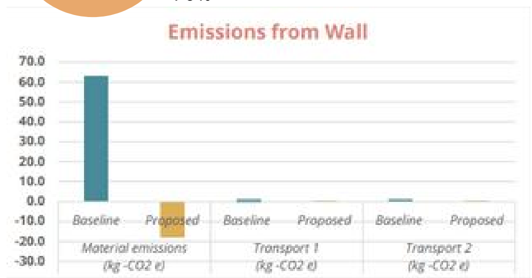


- Use of moulds instead reduces embodied carbon
- Use of block jointing adhesive eliminates the need for cement mortar (wet jointing)
- Each block has a profile for interlocking along with voids of 55mm diameter for inserting a 50mm diameter bamboo pole which holds the bricks together.
- Easily dismantlable
- 109,400 Zerund blocks and 2800 Bamboo poles (50mm dia) are used for the entire building

The embodied carbon emissions per functional unit of the wall is **-17.3 kg-CO2 e** (implies carbon negative)







Paint + 15mm external plaster + 200mm AAC Blocks + 15mm internal plaster + paint

19mm external lime plaster with a natural pigment + 200mm zerund bricks with bamboo poles + 40mm air cavity + 6mm bamboo mat boards

Figure 10.3.a Graph showing EC reduction for wall

MATERIAL PASSPORT
ZERUND

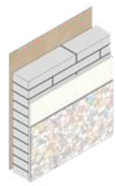
Date of first use:
Date of second use:
Usable life left:

Changes in physical character after first use:
Changes in strength after first use :
No. of reuses:

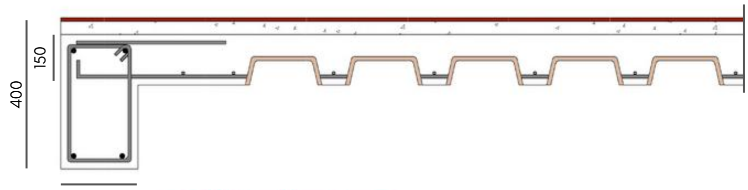
Name : Zerund Brick	High tensile and compressive strength
Material : Plastic ,Ash, Cement, water	35% of air conditioning load reduction
Dimensions : 600 x 20 x 100 mm	30% cost reduction due to lesser dead load
Method of fixing : Block jointing adhesive	Dismantlable
Founded in : 2018	Fire resistance
Place of Manufacture : Guwahati , Assam	Thermal and sound insulation
Compressive strength : 38 - 45 kg / cm^2	Pest resistance due to organic matter
Dry density : 900 - 1100 kg/cm^3	Environment friendly (carbon negative)
Fire resistance : 6 - 7 hours	Lightweight
Cost reduction factor : 30%	Lesser construction time than red clay bricks
Water absorbtion : 6 - 7%	Easy workability, cutting, grooved, nailed, drilled
Thermal conductivity : 0.16 W/m-k	Non weathering effect
Drying Shrinkage : 0.04%	Earthquake resistance

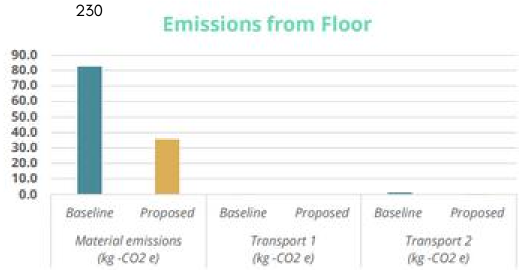
Figure 10.3.b Showing Zerund brick material passport

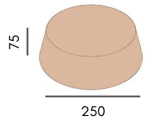
The external walls are made using the Zerund blocks with circular voids for the bamboo poles. 5340 sq.m of the bamboo mat board is used throughout the building for internal cladding of the external walls. The walls on the south facade are lined with pieces of mosaic reclaimed from nearby sites. Lime plaster is used for the external plastering, the labor required is available

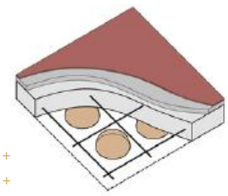


Floor and slab (58% decrease)









150mm RCC slab + 50mm mortar bed + kota stone

150mm filler slab (clay pots) + 40mm IPS flooring + 10mm red oxide coating

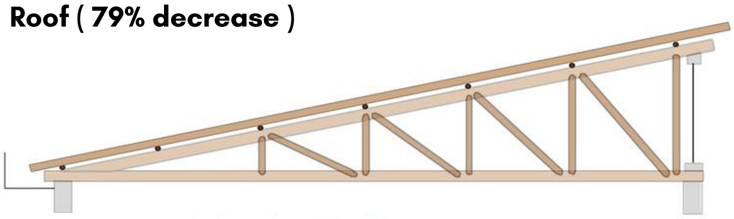
Figure 10.3.c Graph showing EC reduction for floor

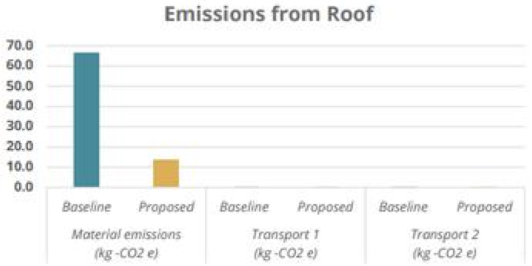
The filler slabs are made using local terracotta pots, ACC Ecomaxx concrete, and steel reinforcement. The clay pots are made using red/brown soil, ash powder, and water. The use of clay pots results in a 30% reduction of slab concrete, promotes the local industry, and adds aesthetic value to the space.

The flooring comprises a 40mm IPS flooring with a 10mm red oxide mix. Natural oxide pigments are added to get the desired color. The flooring is durable, cost-efficient, and easy to maintain.

The embodied carbon emissions per functional unit of the floor are **35.4kg - CO2 e**

Roof (79% decrease)

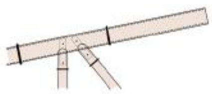




150mm RCC slab + 40mm screed concrete + Bitumen waterproofing course

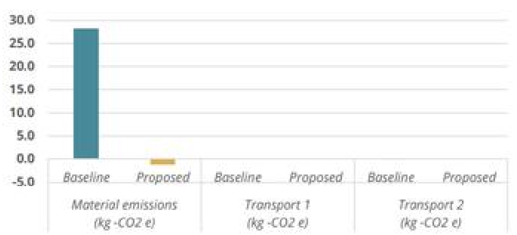
Bamboo truss (main members and struts) + Bamboo corrugated roof sheet (carbon sequestering) with glass wool insulation

Figure 10.3.d Graph showing EC reduction for roof



- The Northlight truss members are entirely made using bamboo hence it is carbon sequestering.
- The members of the truss are of three lengths: 6m, 7.5m, and 9m, and of 140mm and 75mm diameters. 175 such trusses are used.
- Bamboo is treated onsite and the truss is fabricated onsite, hence reducing the transport emissions in comparison to using a prefabricated truss. Fishmouth joints are used hence eliminating the need for gusset plates.
- Brushbond-coated bamboo corrugated sheets are used as sheeting material along with glass wool insulation.
- Manual labor for truss fabrication instead of concrete pumps for casting the final roof (like in the base case) resulted in a further reduction of EE.
- The embodied carbon per functional unit is **13.8 kg - CO2 e**

Fenestrations (104% decrease)

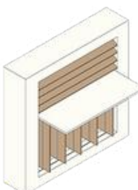


Assam hollock timber frame

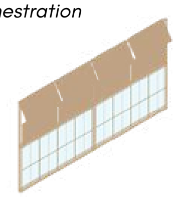
Bambooply frame + Bambooply shutter

Figure 10.3.e Graph showing EC reduction for fenestration

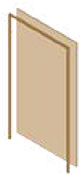
- The louvers are made using beaten bamboo and are treated on-site. Stabilized clay mixed with rice husk, bamboo fibers and lime is used for the chajjas.
- The doors are made using Bamboo ply. The total quantity of bamboo ply used is 300 sqm.
- The embodied carbon per functional unit is **-1.1 kg CO2 e**, this implies that it is carbon sequestering.



Beaten bamboo louvres
50mm Chajja - Bamboo + Stabilized clay mixed with rice hask + lime



Bamboo louvres + Double glazed window with 6mm solar control glass + 13mm air gap + 6mm clear glass



Bambooply door frames + bambooply shutters

Bamboo used for fenestrations , roofing , wall cladding , furniture , partitions

Species of bamboo : **Bambusa Balcooa**

Collection of raw bamboo on site
↓
Preparation of bamboo
(Cut into 6m long poles , Cleaning the nodes and incision and holing of culms)
→ Preparation of boric and borax solution
→ Soaking the bamboo poles in a tank for 10 days
(7m x 3m tank ; can hold 300 - 400 bamboo poles)
↑
Stacked in a shaded place (3 -5 days for diffusion)

Preparation of boric and borax solution
↓
Boric and Borax solution - disposal
↓
- Reused for couple of batches
- Water is being used for construction
- Termite treatment of foundations

The extensive use of locally available bamboo has led to incorporating a bamboo plantation as part of our design. These grow rapidly and can be harvested in a span of 3 to 5 years. It releases 35% more oxygen than an equivalent stand of trees. Further, it also helps to sequester carbon dioxide and maintain a healthy environment for the users.

Structure – Columns and Beams (47% decrease)

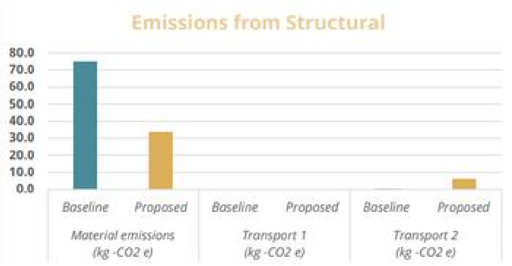


Figure 10.3.f Graph showing EC reduction for structure

- The main structure; columns, beams and foundation is made using RCC. The concrete used is ACC Ecomaxx green concrete which has 45% lesser embodied carbon compared to ready-mix concrete , hence even though the transport emissions are a bit higher than the base case transport emissions, ACC Ecomaxx concrete was chosen.
- ACC Ecomaxx uses fly ash, recycled concrete aggregates and aluminium can fibres . It is used along with steel reinforcement
- Since the site falls in earthquake zone V the structure is built without any compromise on the strength.
- The embodied carbon per functional unit is **39.8 kg-CO2 e**
- Since isolated footing was opted instead of pile / raft foundation , the amount of excavation was reduced hence reducing the EC.

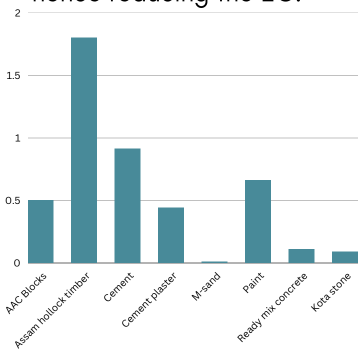


Figure 10.3.g: Graph showing EC factors – base case

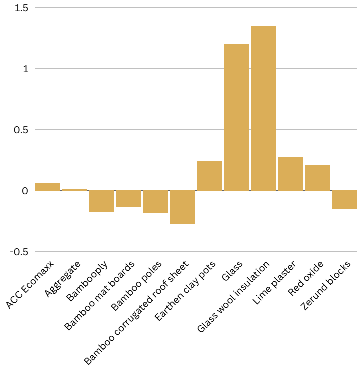
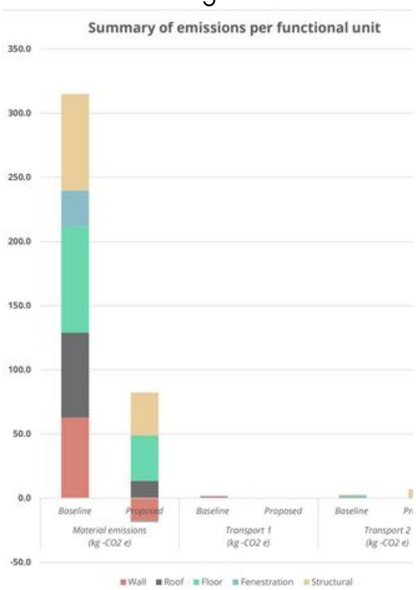


Figure 10.3.h: Graph showing EC factors – design case

MATERIAL	SOURCING DISTANCE (KM)
AAC Blocks	30
Assam hillock timber	25
Cement	6
Cement plaster	6
M-sand	12
Paint	9
Ready mix concrete	35
Kota stone	35
ACC Ecomaxx concrete	158
Aggregate	30
Bambooply	67
Bamboo mat boards	112
Bamboo corrugated roof sheets	148
Earthen clay pots	6
Glass	12
Glasswool insulation	51
Lime plaster	10
Red oxide	6
Zerund Bricks	112

Table 10.3.1: Material sourcing distances – designcase and basecase

- The EC factors have been taken from ICE (BSRIA guide)
- All the materials have been sourced from a 160km radius around the site , these materials are considered local according to USGBC LEED V.4



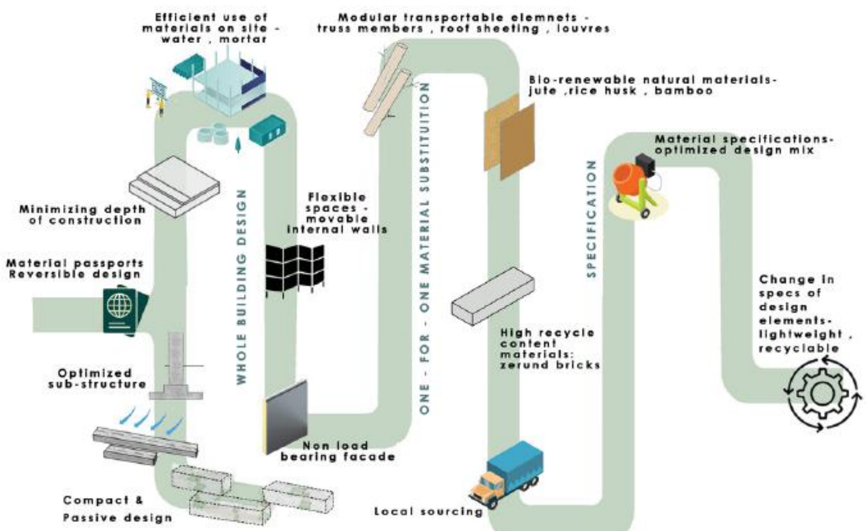


Figure 10.3.i Three stage approach for the reduction of embodied carbon

System Type	Baseline: Material emissions (kg -CO$_2$ e)	Baseline: Transport 1 (kg -CO$_2$ e)	Baseline: Transport 2 (kg -CO$_2$ e)	Baseline: Total (kg -CO$_2$ e)	Proposed: Material emissions (kg -CO$_2$ e)	Proposed: Transport 1 (kg -CO$_2$ e)	Proposed: Transport 2 (kg -CO$_2$ e)	Proposed: Total (kg -CO$_2$ e)
Wall	62.7	1.2	0.7	64.6	-17.6	0.0	0.3	-17.3
Roof	66.2	0.3	0.2	66.8	13.6	0.0	0.2	13.8
Floor	82.6	0.3	1.3	84.2	35.3	0.0	0.2	35.4
Fenestration	28.2	0.0	0.1	28.3	-1.3	0.0	0.1	-1.1
Structural	75.2	0.0	0.1	75.3	33.6	0.0	6.2	39.8
		Grand Total emissions per functional unit (kg -CO$_2$ e)		319.2		Grand Total emissions per functional unit (kg -CO$_2$ e)		70.7

Table 10.3.2 EC reduction in emissions per functional unit

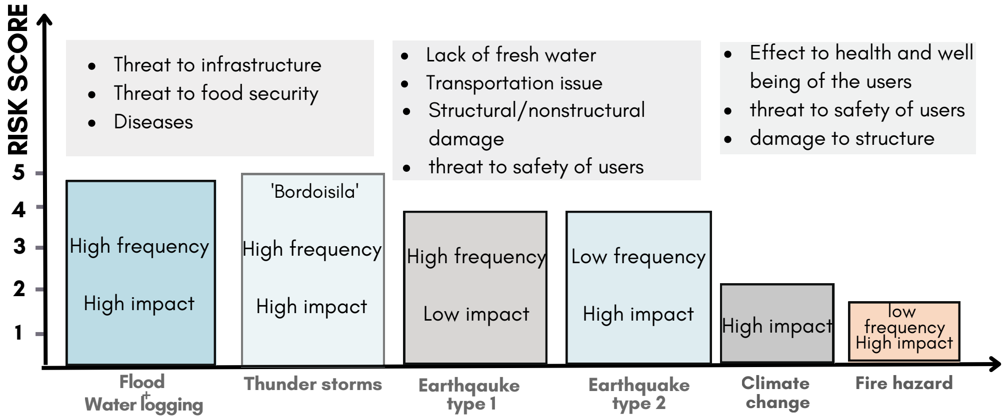
Refer to appendix page 64-65 for detailed calculations

77% reduction in embodied emissions per functional unit in comparison to the base case

10.4 RESILIENCE

SITE - The site is a multiple hazard zone prone to earthquakes and floods (including water logging)
Earthquake Resilience: Nagoan, Assam lies in Zone V(as per IS 1893, 2016 code)
Flood Resilience: The area is subjected to frequent flooding by rivers for 4 months a year. The average annual rainfall between June and September is 1,560 mm. Reference- http://sdmassam.nic.in/

MULTI HAZARD RISK ASSESSMENT



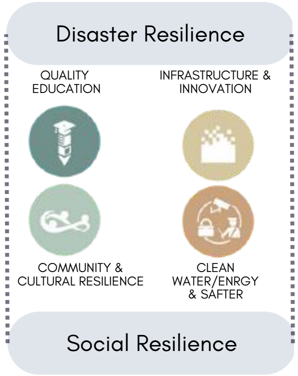


Figure 10.4.a: Graph showing frequency and impact of various hazards onsite

CRITICAL FUNCTIONS OF THE BUILDING-

CRITICAL FUNCTIONS	FLOOD	EARTHQUAKE(type 2)	THUNDERSTORMS	FIRE
Lights	✓ 50%	✓ 50%	✓ 50%	✓ 50%
Ceiling fans	✓	✓	✓	
Sockets	✓ 15%	✓ 15%	✓ 15%	
Communications(Fire Alarm, CCTv)	✓	✓	✓	
PHE	✓	✓	✓	✓
Cooking(Refrigeratror, Induction)	✓	✓	✓	
First responder medical equipment	✓	✓	✓	✓
ENERGY REQUIREMNT DURING HAZARDS	1600 KWh	1500 KWh	1700 KWh	1300 KWh
Number of days	4	3	4	3

Table 10.4.1 Matrix of building systems (energy required during hazards stored at site)
For detailed calculation refer appendix 12.8, table 12,13,14,15 - pg 59

1.ENERGY EFIFICIENCY - The total energy that needs to be stored for withstanding 4 days of pandemic-**5900KWh** (achieved).

2. WATER RESILIENCE

occupants activity	Proposed case	
	quantity in l/person/day	Quantity in lts for 500 people for 4 days
handwash	5.4	2700
drinking	5	2500
kitchen	5	2500
shower	15	7500
cleaning	5	2500
washing	14	7000
urinal flushing	0	0
wc flushing	1.12	560
total	50.52	101040

Table 10.4.2 Water requirements during disaster

3. FOOD RESILIENCE

LPG requirement for 900 people	
Type of cylinder	Commercial 19kgs
1.2 cylinders/day	22.8kgs/day

During disaster (flood / Earthquake)

Number of days to be catered	7
Amount left after comsumption/day	14.66 kgs/day
Amount (kgs) saved per/month	51.6kgs/month
Amount saved for 3 months	293.2 kgs
Number of people catering	2000
Biogas used per/day	45.5 kgs
Number of days sufficing during disaste	6 to 7days

Table 10.4.3 Biogas requirement during disaster

Figure 10.4.b: Diagram showing how food resilience is achieved

ORGANIC FRAMING

COMPOST FROM BIOGAS (Kg/day)	COMPOST REQUIRED (Kg/year)
195 kg/day	75,000 kg/year

Table 10.4.4 Compost requirement for 300sqm field
Reference-https://mcgillcompost.com/compost-calculator/

An organic farming method has been used to grow vegetables and fruits. The compost requirements per year have been met by biogas waste and the excess compost is given to the farming community & also used for bamboo plantation on site. Crop rotation and mixed farming techniques are used to increase production. To keep the vegetables fresh, the refrigerated space of a heat pump is used for cooling which takes 7mins to cool down 8 cubic meter of space.

HEAT PUMP USED AS REFRIGERATOR :

Nominal Capacity of Heat Pump = Heat delivered to Water = 40kW
Power input = 8.5kW
Heat absorbed/removed from Refrigerated space = 31.30kW
Thus, the time required to raise the temperature of 1000L of water by 30 degrees = 1 hour approximately

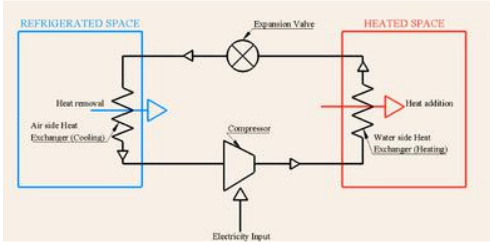


Figure 10.4.c: Heat Pump

Since the refrigerator needs to be operational for 24hrs a day, the 1 hour of operation is split into 3-minute intervals of operation per hour, which is further split into six 30-second intervals. This ensures that the refrigerated space remains cool while the water is also heated.
In addition, from calculations, it takes the air in the refrigerator roughly 8-10mins to heat up by 5 degrees, and thus, the 30s intervals of burst operation are sufficient to maintain the required temperature range.
Extra energy is being stored in batteries.

DESIGN INTEGRATION of STRUCTURE :

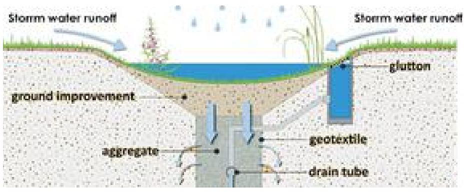


Figure 10.4.d: Bioswale section

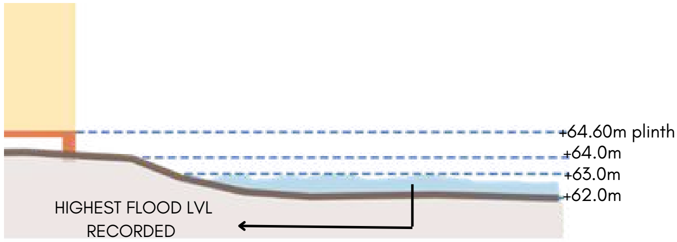


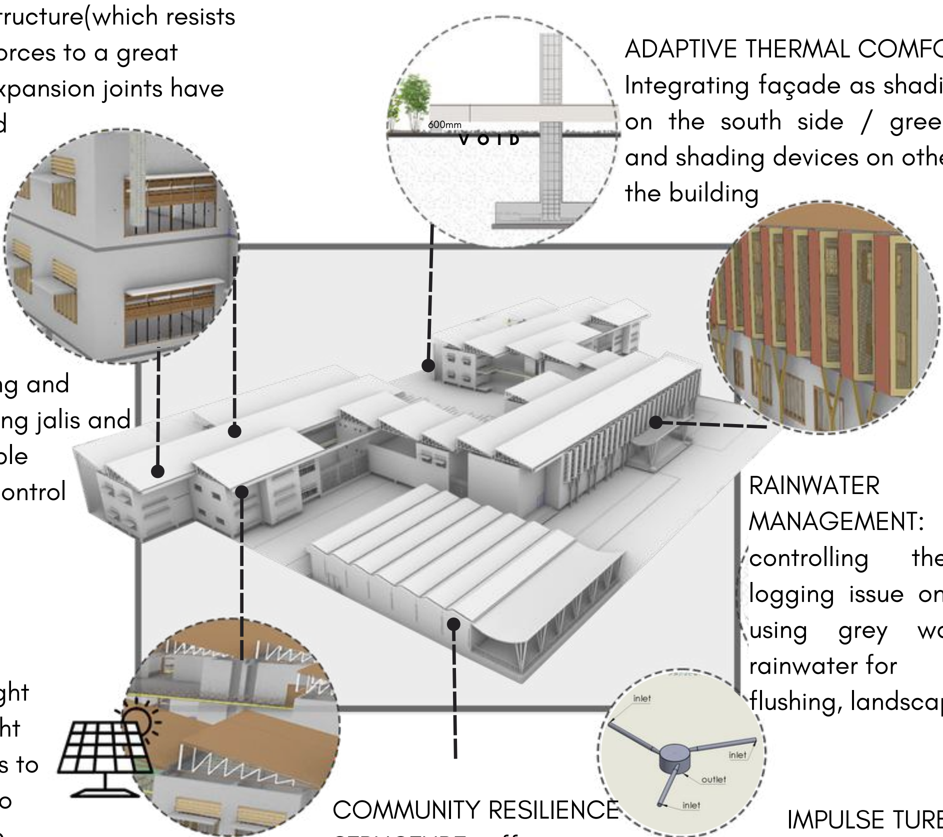
Figure 10.4.e: Section showing hollow plinth and peak flood level

FLOOD PROOFING STRATERGY(Elevated Porous Plinth): Plinth is raised and bioswales are added on the site to prevent severe flood affects

Reference- http://sdmassam.nic.in/

STRUCTURE Designed according to IS 1893 Part1-2016,IS 800
RCC frames structure(which resists hydrological forces to a great extent) with expansion joints have been designed

ADAPTIVE THERMAL COMFORT: Integrating façade as shading device on the south side / green screens and shading devices on other sides of the building



Natural lighting and ventilation using jalis and locally available materials to control humidity

RAINWATER MANAGEMENT: controlling the water logging issue on site and using grey water and rainwater for flushing, landscaping etc

Using north light for natural light and PV panels to attain net zero energy on site

COMMUNITY RESILIENCE STRUCTURE- efficient communication (fire extinguishers, hose reels etc and exits are clearly defined

IMPULSE TURBINE

Figure 10.4.f: Diagram showing all aspects of resilience within the structure

FLOOD RESILIENCE –

SIGNAL VARIABILITY

PREPAREDNESS/MITIGATION	RESPOND	RECOVER
The window layers include mosquito mesh + bamboo jali + shutter.Large overhangs- protect from rainwater. Providing ceiling fans for continuous air flow (3)	Checking for leaks, damage clearing the debris and repairing the damage of the most required emergency spaces (6)	Releasing the stagnant water from in & around the building to prevent outbreaking of water borne diseases (9)
Creating resilience in landcape design by creating bioswales & ridges to prevent damage from water logging, debris and harsh flow of flooding water (2)	use of partiton walls to seperate people in case of a disease outbreak (5)	Keep students, staff, and visitors safe from damaged and/or flooded areas of the campus. (8)
Flood Proofing stratergy- The structure has been raised above the plinth to avoid flooding in the building (1)	Guaranteeing emergency stay of local people for a few days by incorporating evacuation & utilizing emergency food, water, and energy storage. (4)	Repairing the roof drainage . Repairing /Replacing and rechecking the structural system, walls, panels , floors ,etc (7)

FLOOD /WATER LOGGING RECOVERY PLAN

Figure 10.4.g: Diagram showing flood resilience

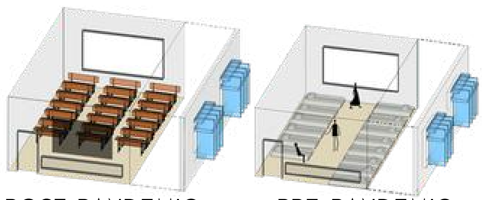
-Considering the highest flood level as 61m above sea level(Assam Disaster managment Authority), the site is located at 64m above sea level and plinth of 600mm is provided for extra safety.

-At vulnerable points in structures like the services, cables etc. are also located above plinth level and are coated & sealed with water resistant sealants.

-Shelter for livestock is also present in the site above the rain water tank, made of bamboo (temporary structure)

The complete school and MPH Structure will act as a community resilience centre.
It can cater to up to 500 people (with beds) within a radius of 1-2km around the site

14 beds / CLASS
Total classes =42
Total beds = 588-600



POST-PANDEMIC PRE-PANDEMIC

Figure 10.4.h replacing of benches with beds during disaster

EARTHQAUKE RESILIENCE –

SIGNAL VARIABILITY

PREPAREDNESS/MITIGATION	RESPOND	RECOVER
In case of fire outbreak the construction materials - exterior walls have fire rating of 6-7 hours and internal upto 2-3 hours (3)	Clearing the debris and repairing the damage of the most required emergency spaces (6)	Help the community recover from disaster educate them for the reconstruction of their homes , help them rebuild the community back (9)
Building catering to 500 people including the community around with 5 days of amenities available - Community Resilience shelter (2)	Instantly providing required emergency services and managing the health & well-being of the occupants (5)	Managing the basic requirements of the occupants. Repairing the additional facilities like W/C's , communication systems, etc. (8)
STRUCTURE Designed according to IS 1893 Part 1-2016,IS 800 and expansion joints are designed in places required (1)	"EARTHQUAKE - DROP" students should immediately take cover under desks or tables and turn away from the windows. (4)	Repair restore electrical. mechanical appliances which can cause harm. Keeping the Fire exits clear & allowing movement of vehicles into the site for rescue (7)

EARTHQUAKE RECOVERY PLAN

Figure 10.4.i: Diagram showing earthquake resilience

Only the MPH structure will act as a community resilient structure during high impact and/or high frequency hazard events.

Earthquake Building Type- RCC framed structure with expansion joints makes it resilient to high frequency, low impact earthquakes.

SEISMIC SIMULATION- high frequency low impact earthquake

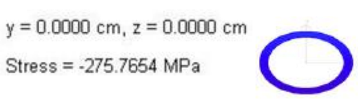


Figure 10.4.j Results of seismic simulation

Seismic simulation for zone V earthquake has been carried out for the Multi-Purpose Hall - BAMBOO PORTAL FRAME STRUCTURE which also acts as the main space for community resilience.
Detailed calculations have been mentioned on pg-44 (appendix)

SCAN HERE!
(simulation video)

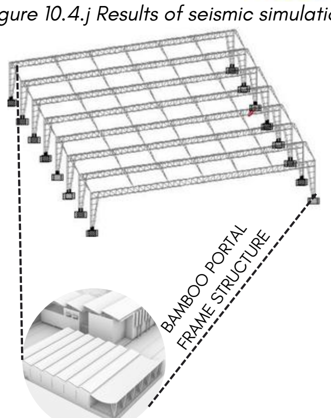


Figure 10.4.k: Bamboo portal frame structure for MPH

MPH works as a mixed mode ventilated space

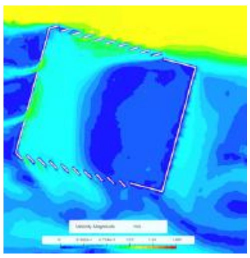


Figure 10.4.l Wind simulation for the MPH

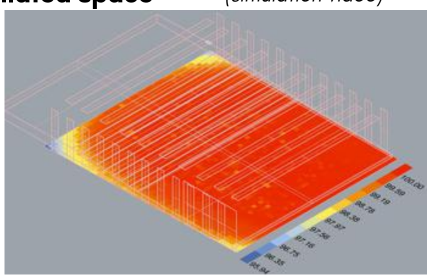


Figure 10.4.m Daylight simulation for the MPH

FIRE RESILIENCE

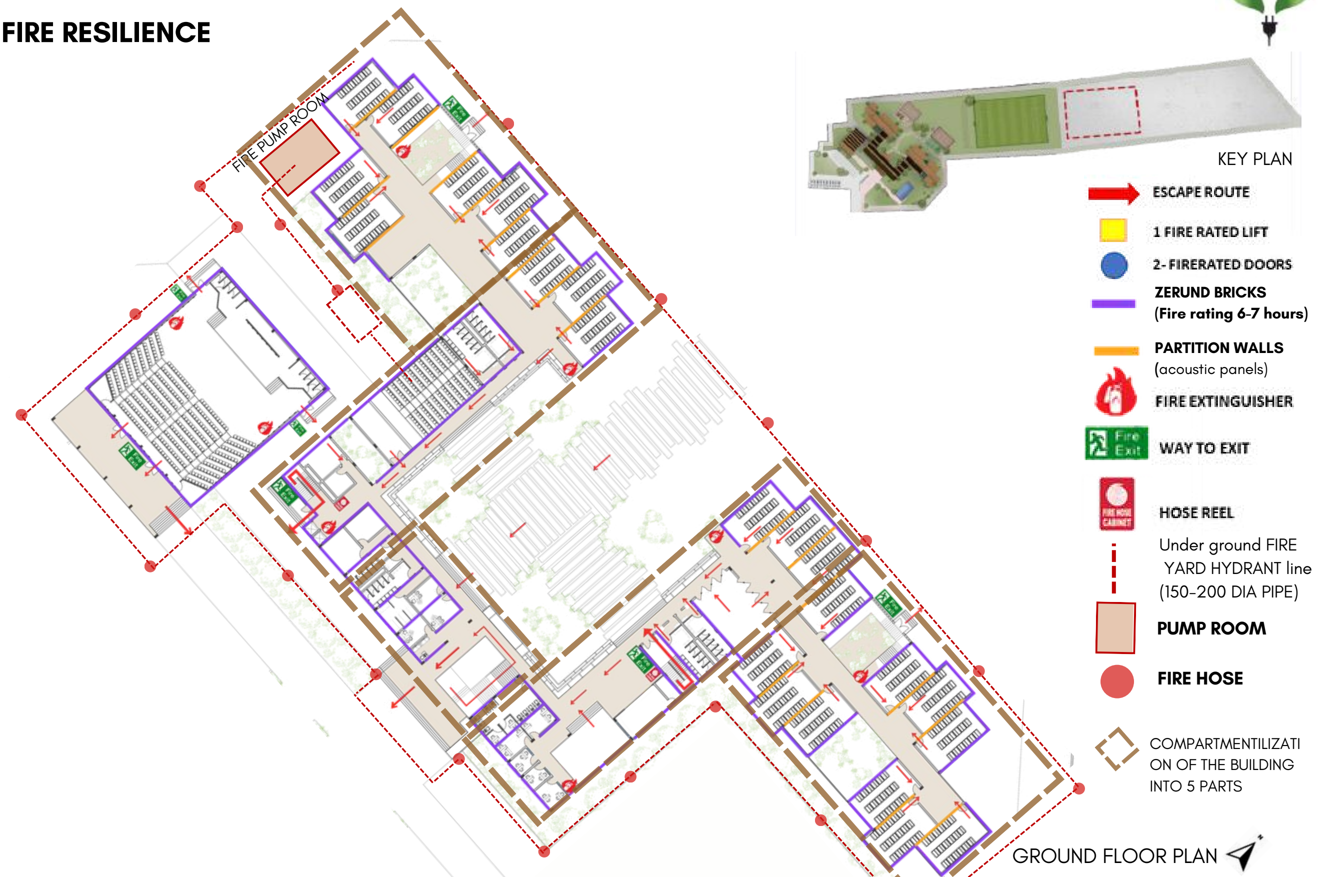
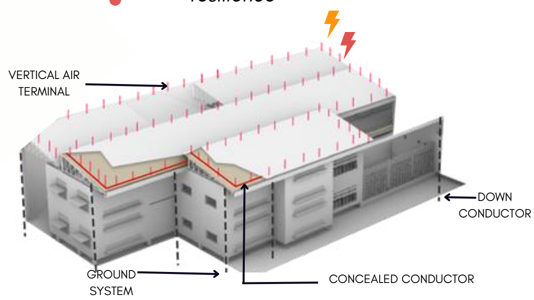


Figure 10.4.n: .Floor plan showing fire resilience

BUILDING MATERIALS	FIRE RATING
RCC(M25) - framed structure	3-4 hours
Zerund bricks(250mm)	6-7 hours
Bamboo panels(110mm)	resists upto 400 C
Bamboo truss	resists upto 400 C
Structural glazing (north light)	60-120 minutes
Bamboo corrugated roof sheeting	resists upto 400 C

Table 10.4.4 Fire rating of the major materials used in construction

The type of constrution according to fire resistance- TYPE 1 construction (NBC)



Building protection against lightning during a thunderstorm called 'Bordoisila' which occurs every year before the start of the monsoon carrying heavy winds/rains/thunder/lightning

CLIMATE CHANGE RESILIENCE -

Deriving the trend line from the existing data for the next 15-20 years of the building. As seen in the graph the temperatures increase, hence the building has been designed accordingly

As the humidity is decreasing and the rainfall is increasing, bioswales and drainage systems have been put in appropriate locations to prevent debris blockages and backflow of water. The excess water is going to be used for future expansion.

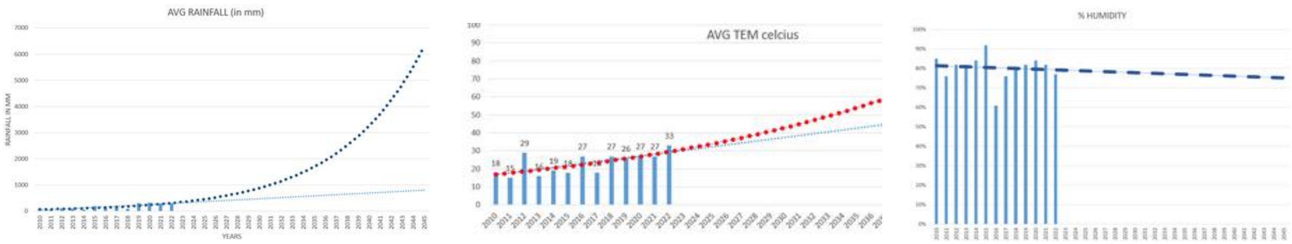


Figure 10.4.o: Trend lines for rainfall, temperature and humidity

https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,guwahati-assam-in,India

The solar panels can also be added on the roof of the existing building for more power generation on the site during the future construction-3000 sq.m area is available (Extra energy produced would be 417160 KWh/year)

10.5 ENGINEERING AND OPERATIONS

EXPANSION JOINT

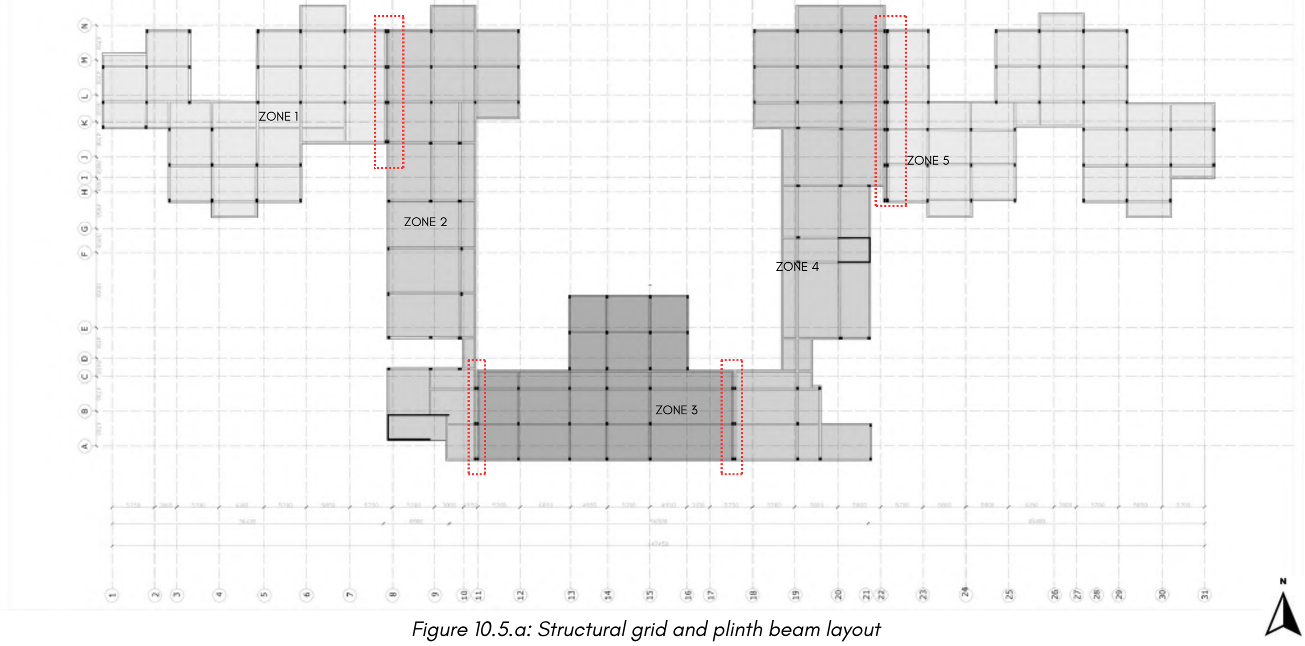
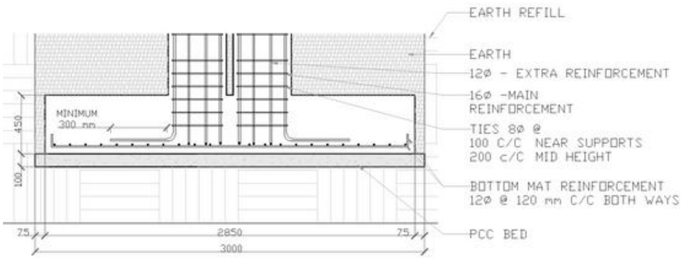
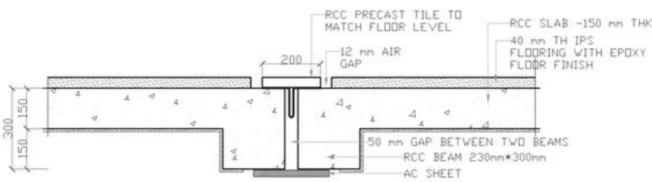


Figure 10.5.a: Structural grid and plinth beam layout



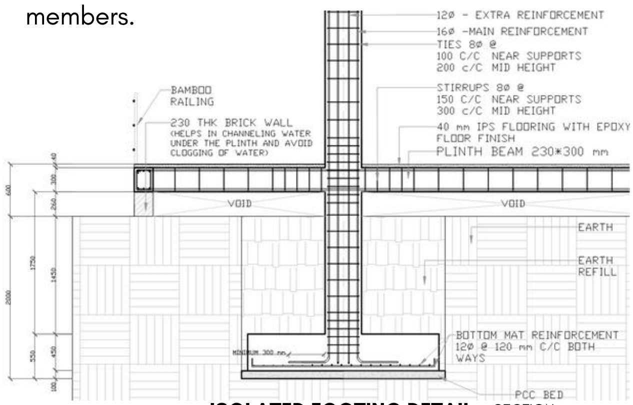
EXPANSION JOINT -FOOTING DETAIL
SECTION



EXPANSION JOINT -BEAM DETAIL SECTION

Figure 10.5.b: Details of expansion joint of footing and beam

The site is located in Seismic Zone 5 and due to frequent flooding, the building has been divided into **FIVE ZONES** with 4 expansion joints (marked in red lines) in between for a safer structural system. Also, the building spans a large distance which might cause cracks due to uneven settlement of the earth. A gap of 50 mm is given between the two structural members.



ISOLATED FOOTING DETAIL SECTION

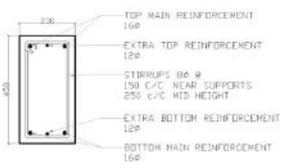
STRUCTURE

All calculations are done manually, keeping in consideration the site constraints (Seismic Zone 5, flooding and high water table). The design of structural members is in compliance with IS-456. For loads, IS-875(Part 1 and 2) was used as a reference. Loads considered for Live load - 5 KN/m2 and the dead load was considered as 5 KN/m2.

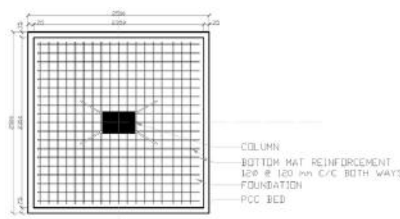
The provision of a Plinth beam, lintel beam and tie beam adds extra strength to the structure to withstand earthquakes.

Span for structure - 6000 mm * 5000 mm
After detailed calculations, the sizes of structural members have been fixed. Details are mentioned below

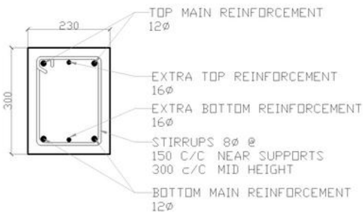
Column : 300mm*450mm
Plinth Beam : 230mm*300mm
Tie Beam : 230mm*450mm
Slab Thickness : 150mm
Footing size : 2500mm*2500mm



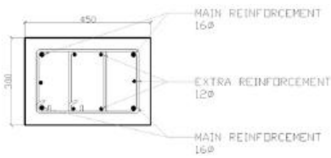
TIE BEAM DETAIL SECTION



FOOTING DETAIL PLAN



PLINTH BEAM DETAIL SECTION



COLUMN DETAIL PLAN

Figure 10.5.c: Details of isolated footing ,tie beam, plinth beam and columns

HVAC

For HVAC, a **VRV** (Variable Refrigerant Volume) system with a **DOAS** (Dedicated Outdoor Air System) was chosen for its efficient performance which requires less space compared to a chiller system and gives access to control temperature at individual zones. In addition to that, the VRV systems can be integrated into the BMS (Building Management System) for efficient energy consumption. As Assam has high humidity, DOAS helps in reducing the dew point and dehumidifies the space which in turn helps the VRV system to work more efficiently.

Company and Model	: DAIKIN RXYMQ6PVE
Conditioned Area	: 1210 Sq Mt
Number of VRV Systems req.	: 14
Cooling power consumption	: 4.44 kW
BTU/hr	: 515137
Tonnage Required	: 42.93
BEE rating	: >4 Star

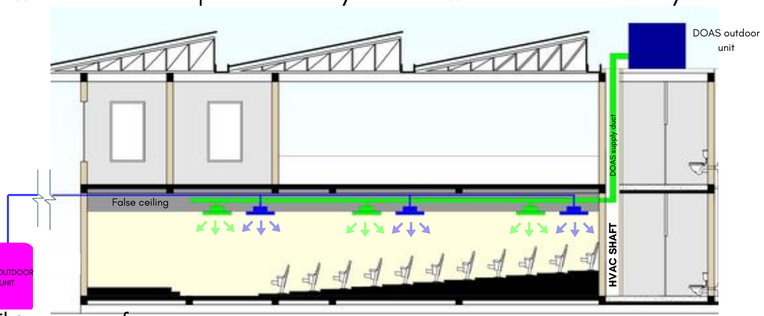


Figure 10.5.d: Section through Seminar to show placement of equipment

The chosen VRV system has a **COP value of 3.67**. This means for every 1kW of electricity input, the VRV system produces 3.67 kW of Cooling. Due to this, the HVAC system is energy efficient.

DOAS sufficiently dehumidifies and tempers the outdoor air to meet both the latent load and the ventilation requirements for all spaces served by the system. (Refer Appendix table 11 on page 58 for detailed explanation on right sizing of HVAC).DOAS outdoor units are placed above the toilet blocks of building as shown in Figure 10.5.d.

Figure 10.5.e: HVAC LAYOUT

DO'S AND DONT'S MENTIONED IN APPENDIX 12.13,pg.no 66

SOUTH FACADE DETAILING

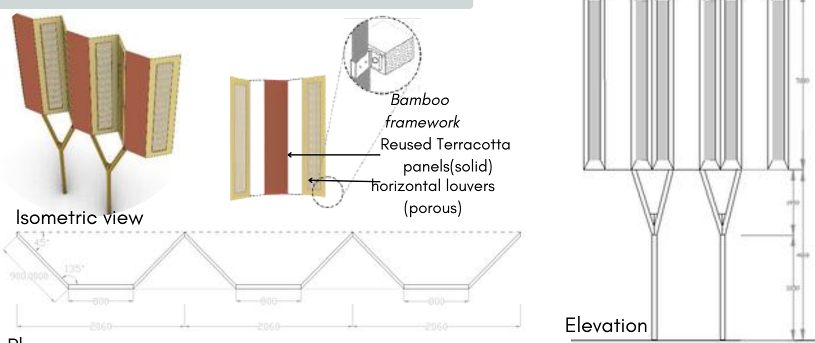


Figure 10.5.f: Detailing of South facade

NORTH FACADE WINDOW

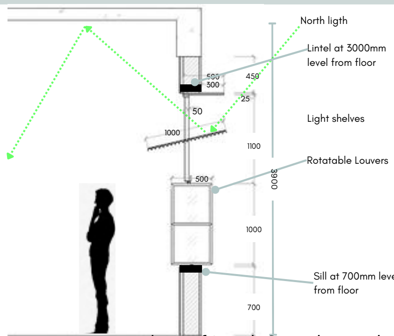
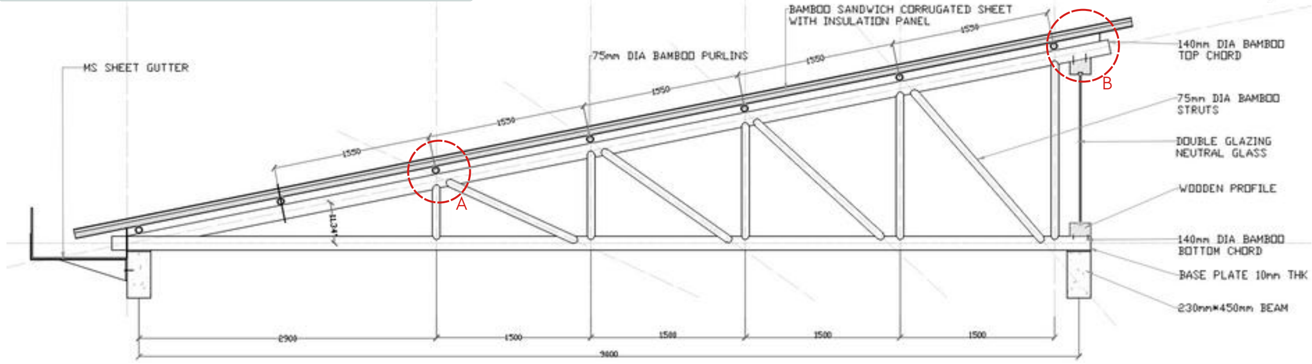


Figure 10.5.g: Detailing of North façade window

A module acting as both a shading device & façade to prevent direct harsh sunlight and allow for air movement. It also helps in reducing the cooling loads for the mixed-mode ventilated spaces placed on the southern side.

NORTH LIGHT TRUSS



SECTIONAL ELEVATION -BAMBOO NORTH LIGTH TRUSS DETAIL

Figure 10.5.h: North light truss

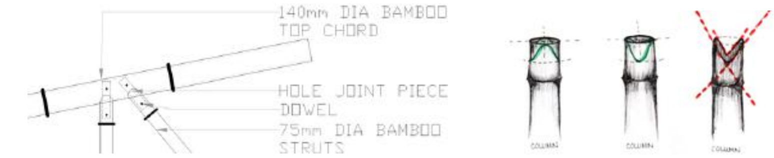


Figure 10.5.i: DETAIL - A (close up detail of fish mouth joint for top chord and struts)

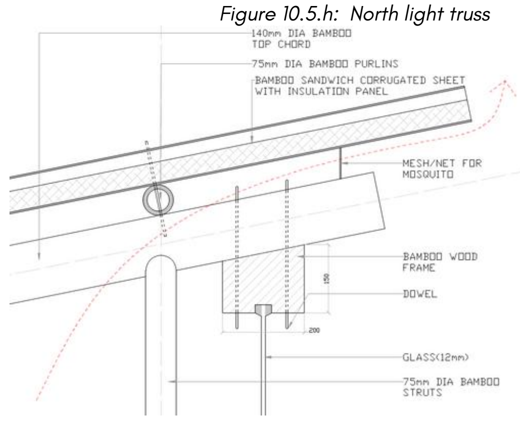


Figure 10.5.j: DETAIL - B (close up detail)

MPH DETAIL

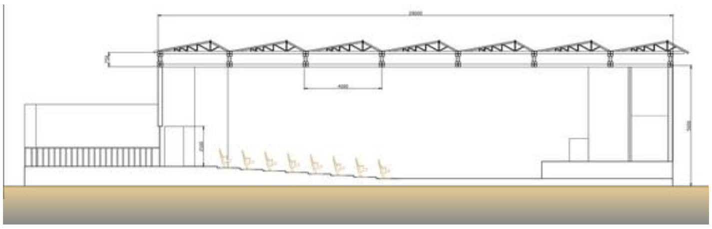


Figure 10.5.k: Section through MPH

A small opening has been created between the roofing material and the top cord, which allows the hot air to exit through the passage(as shown in the red dotted line). To avoid insects to come into the classrooms, a mesh system has been provided

PHE DETAIL

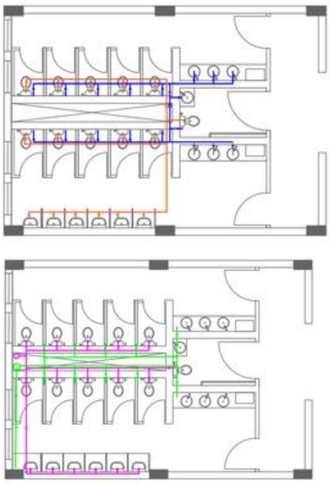


Figure 10.5.l: PHE layout

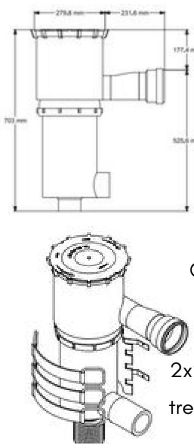


Figure 10.5.m: fl - 500 rainy filter

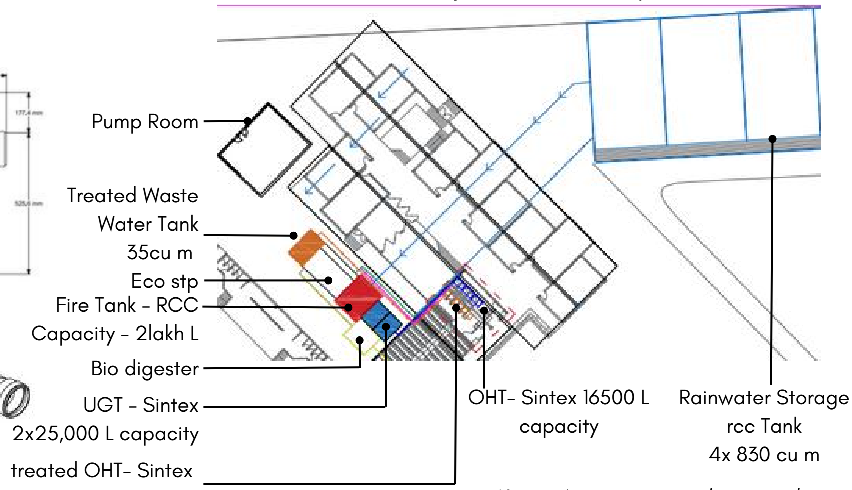


Figure 10.5.n: Water integrated system Plan

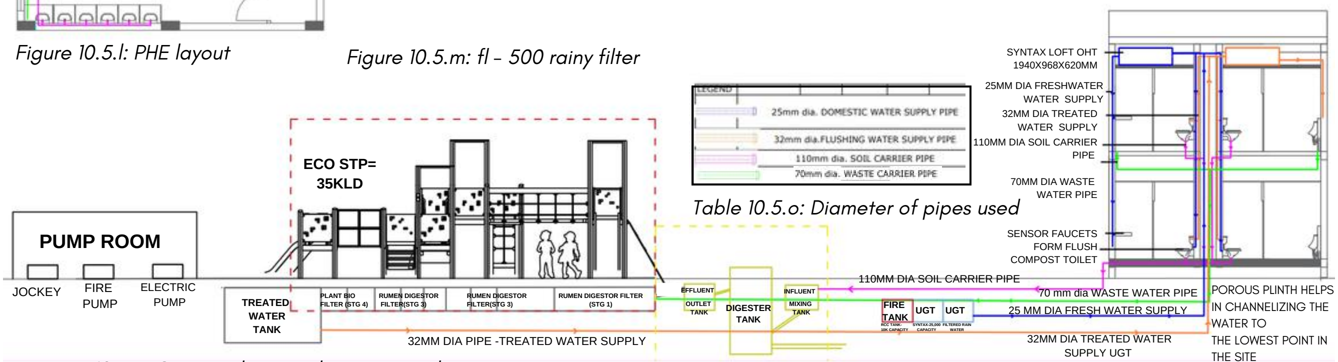


Table 10.5.o: Diameter of pipes used

Figure 10.5.o: Section showing the integrated system

SOLID WASTE MANAGEMENT

As per Assam Urban Solid Waste Management Policy Report(2018), Nagaon generates about 48 metric tons of waste per day. Disposal of this waste is a serious problem at various levels (Micro to Macro). The school is a place where we could help teach students about how effectively we can manage the disposal of waste and induce the knowledge of effective reuse thereby achieving a net zero waste school

A special **R & D Block** (Research and development) can help students with hands-on experience to practice converting waste into innovative products thus bringing in a sustainable thought process in students.

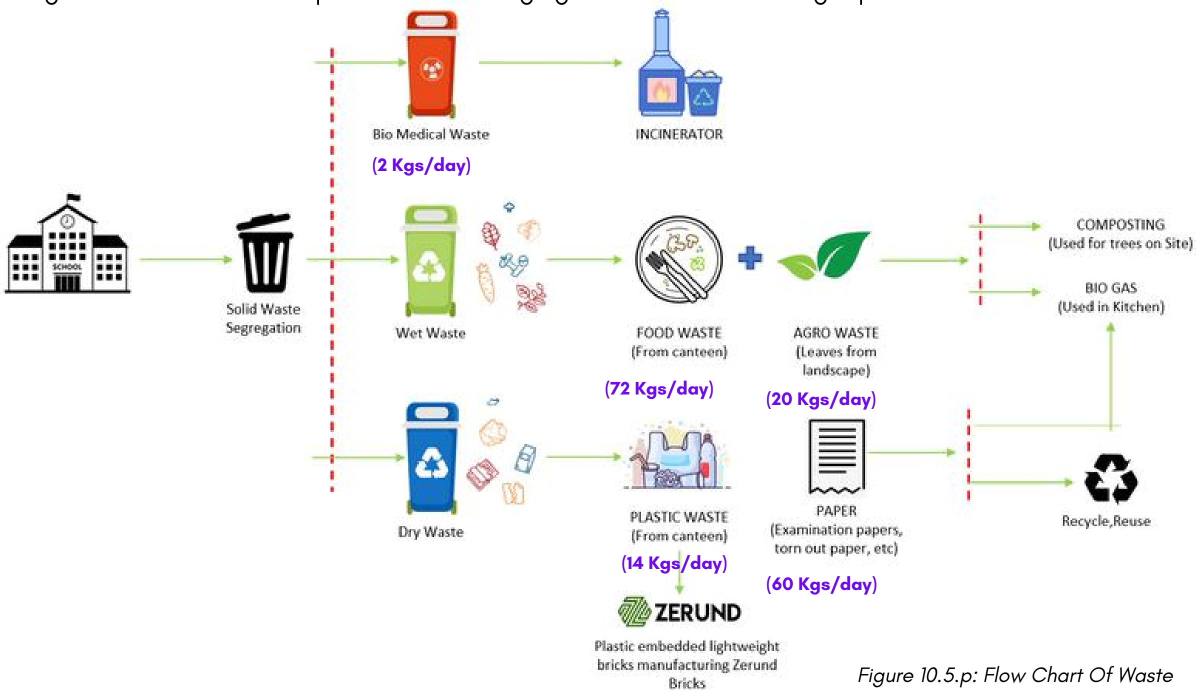


Figure 10.5.p: Flow Chart Of Waste

A few strategies of waste management which could be implemented are :

- Provision of waste bins in all individual spaces to avoid littering and proper waste management could be maintained.
- Nets/mesh under major big trees for ease of collecting them for composting
- Reuse of academic textbooks by passing them on to juniors, thus reducing paper wastage.

As per research based on (*)Solid Waste generation and Management in Schools, Puducherry, schools on average generate 0.092 (±0.025) Kg/per capita/day. As per the area program, our school accommodates 2000 people (1800 students and 200 staff), so the total waste generated is around **184 Kg/per day**. Further, the research suggests that 0.047 Kg/per capita/day of total waste is **Biodegradable**, which means **94 Kg/per day** of solid waste could be used for Composting and Bio-gas. With respect to plastic, the school will be generating **14 Kg/day** of plastics which could be utilized for producing ZERUND bricks. (Detailed tables for values have been shown in the Appendix 12.6-page no. 53)

ELECTRICAL LAYOUT

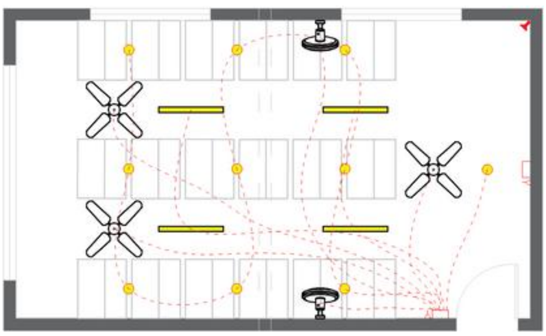


Figure 10.5.q: Typical classroom electrical layout

BMS SYSTEM

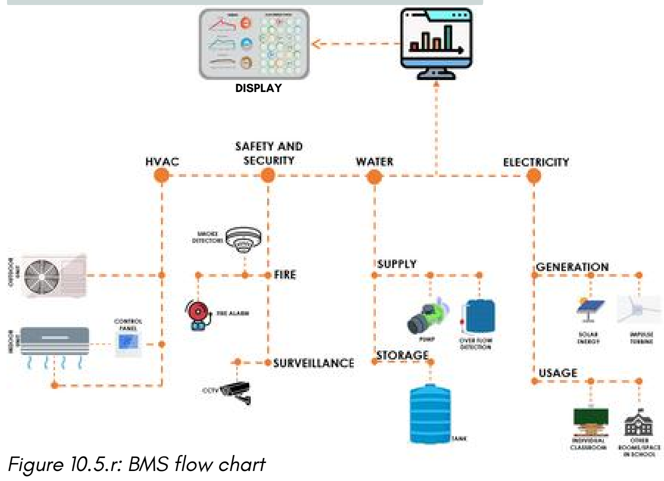


Figure 10.5.r: BMS flow chart

* Rajamanikam Ramamoorthy,Gopalsamy Poyyamoli1, Sunil Kumar(Solid and Hazardous Waste Management Division, Nehru Marg, Nagpur-440 020, India);"ASSESSMENT OF SOLID WASTE GENERATION AND MANAGEMENT IN SELECTED SCHOOL CAMPUSES IN PUDUCHERRY REGION, INDIA"-2019; Published in Environmental Engineering and Management Journal

10.6 ARCHITECTURAL DESIGN

The vision for our green school is to create a sustainable, healthy, resilient, dynamic, inclusive and innovative learning environment that inspires students and staff to make a positive impact on the world.

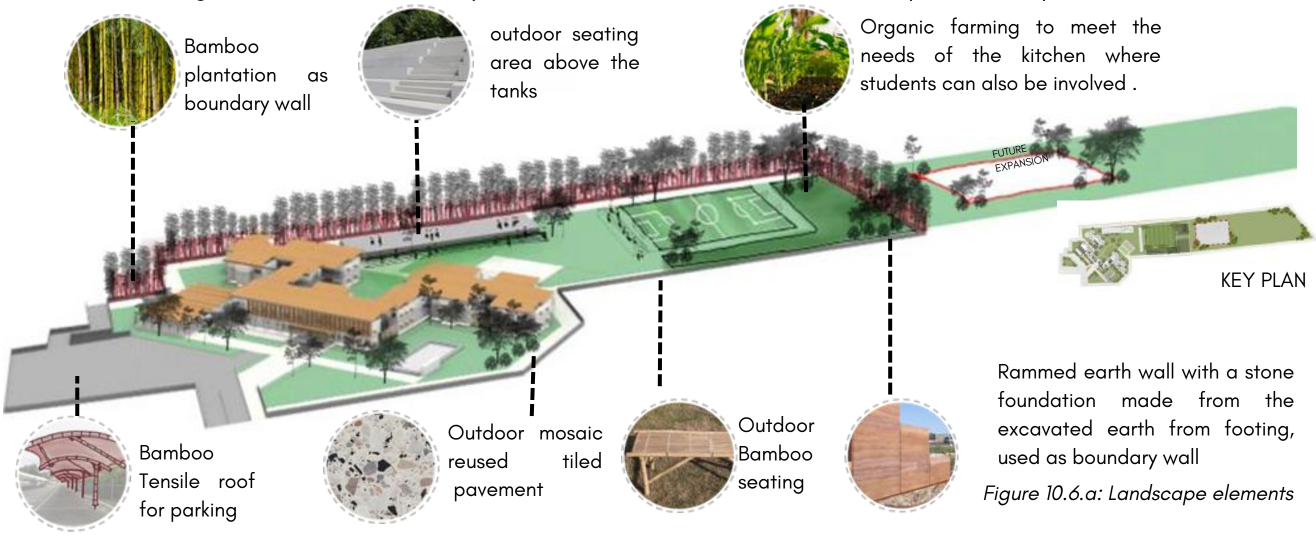
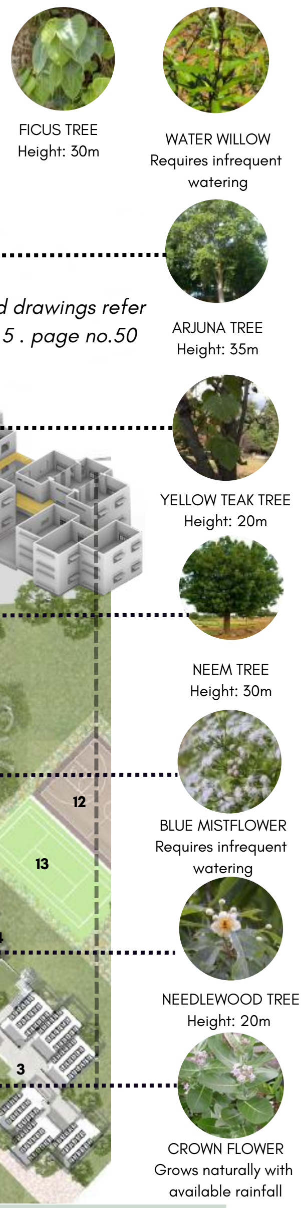


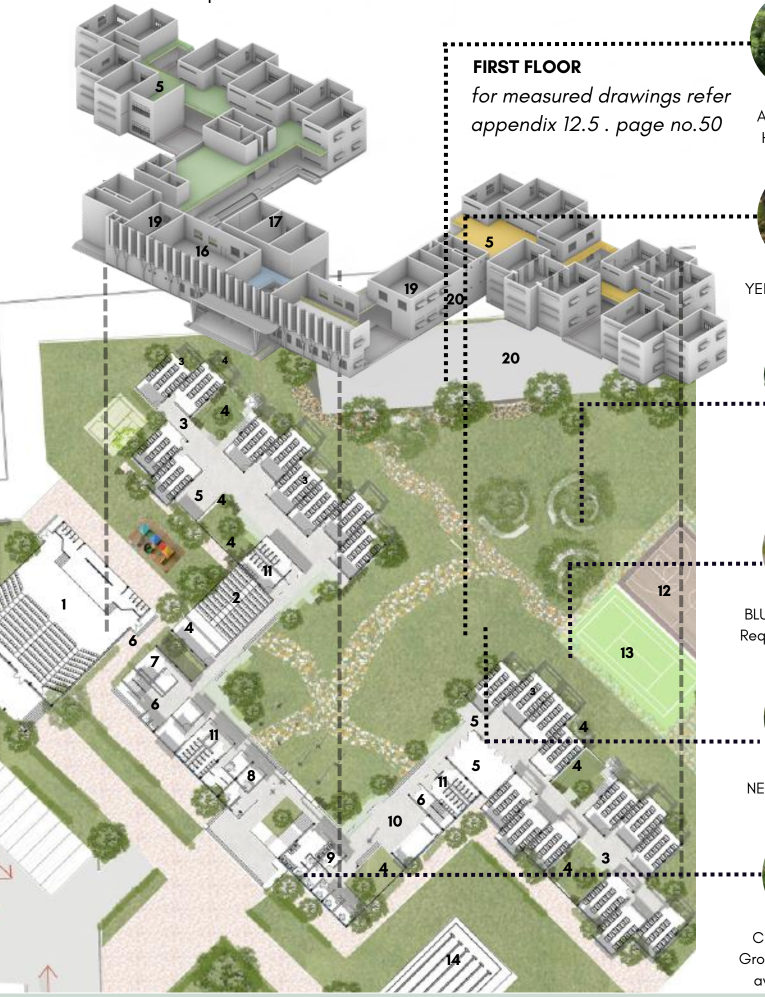
Figure 10.6.a: Landscape elements

The school has been divided in three zones. The admin along with R&D lab and the other labs are designed in such a way that they form the brain of the building, overlooking the entire school. A double height library space surrounding the courtyard provides a favorable reading environment and visual connections. The two wings of the classrooms are facing the wind, north light as well as opening out to the outdoor views. The activity room at the junction becomes an extension to the corridor, keeping it flexible in use. The internal courtyards become the extension to the corridor hence becoming pause points for various get togethers. The corridor around the central courtyard gradually merges with the landscape reducing thermal shock. The staggering of the classrooms creates these nooks and corners for students to get together. Rainwater tanks are designed in such a way that they act as an open air theatre as well as a recreation space.



Gallery of achievements as info-kiosk at the entrance lobby

Intermittent courtyard breakout spaces to increase efficiency of learning



1.Multi-Purpose Hall
2.Seminar Hall
3.Classrooms
4.Courtyards
5.Activity Room
6.Fire Rated Lobby
7.Services
8.Principal /HOD Rooms
9.Staff Rooms
10. Canteen
11. W/c's
12. Basket Ball Court
13.Tennis Court
14. Swimming Pool
15. Parking Area
16. R&D Blocks
17. Labs
18. Library
19.Computer Lab
20. Water Tanks + playground

GROUND FLOOR PLAN

Figure 10.6.b: Floor Plans

Figure 10.6.c: View of sports field

Figure 10.6.d: View of the multi-purpose hall

Porous plinth created by raising the building to avoid water logging on the site

SPORTS FIELD

Proposal to rent out the football field and basketball courts to sports authorities for conducting national level competitions, for other schools in close proximity and can be used as a training/coaching camp for athletes residing near the campus

MPH HALL

Multi-purpose hall to be rented out for other events such as exhibitions, awareness center (sanitation/women empowerment/ vaccination drives/green buildings etc.), indoor sports competitions, workshops / summer camps and for other schools in close proximity

Provision of north light truss for better daylighting

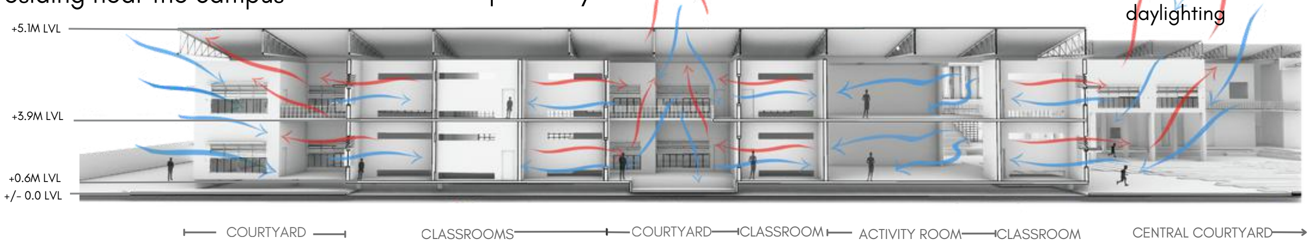


Figure 10.6.e: Section through northern facade

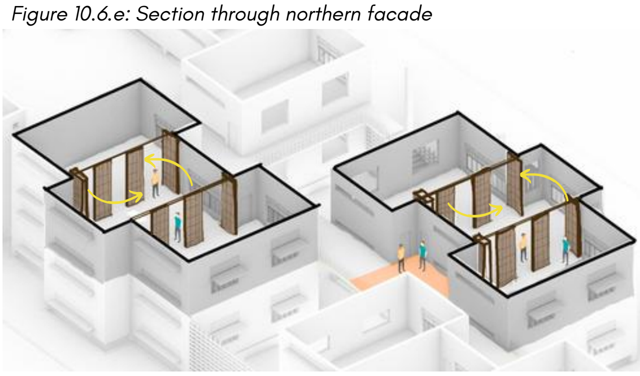
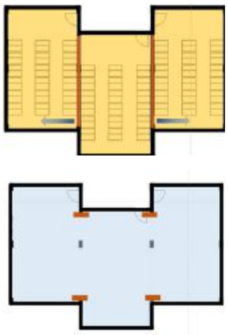


Figure 10.6.f: Interior view of classrooms

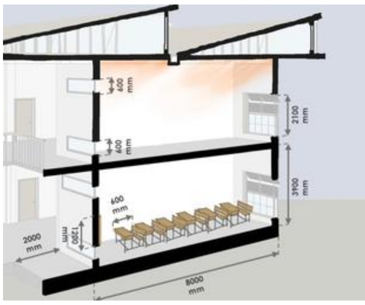


ADAPTABILITY

The **classroom** modules are designed to function as flexible spaces with alternate functions.

A scenario of classrooms converted to an exhibition space or a combined class as shown

Planter boxes used on first floor as visual connection to green spaces

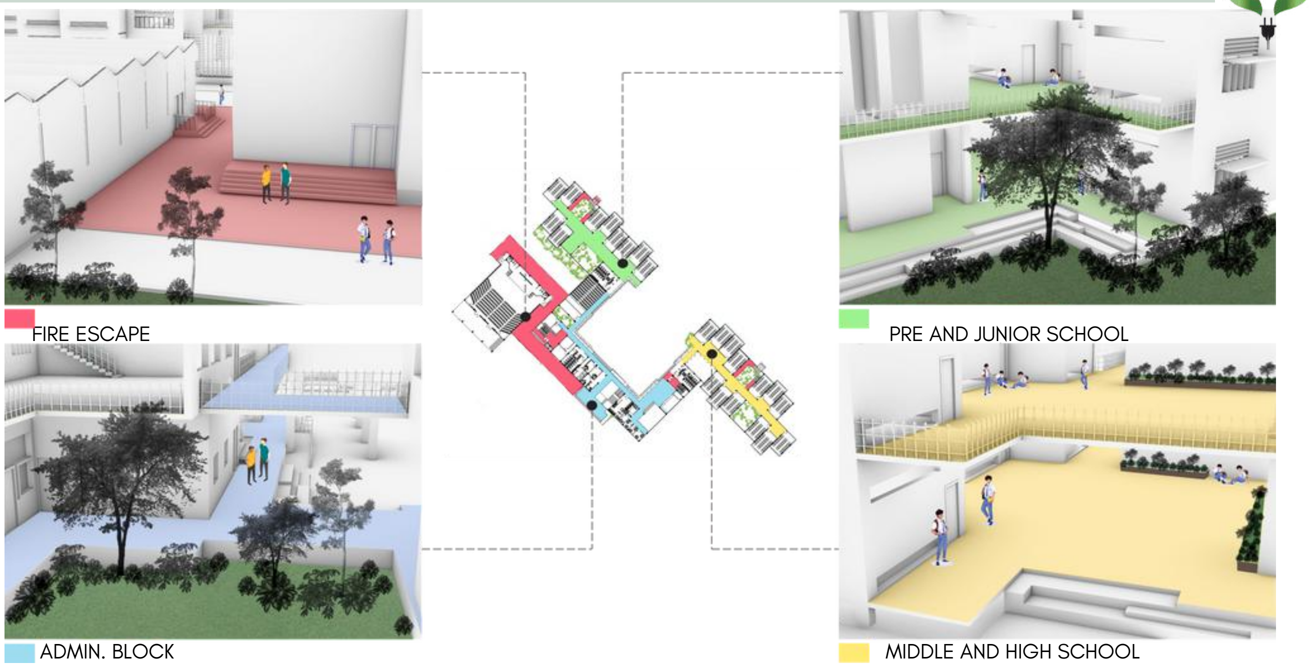


Classroom

Corridor

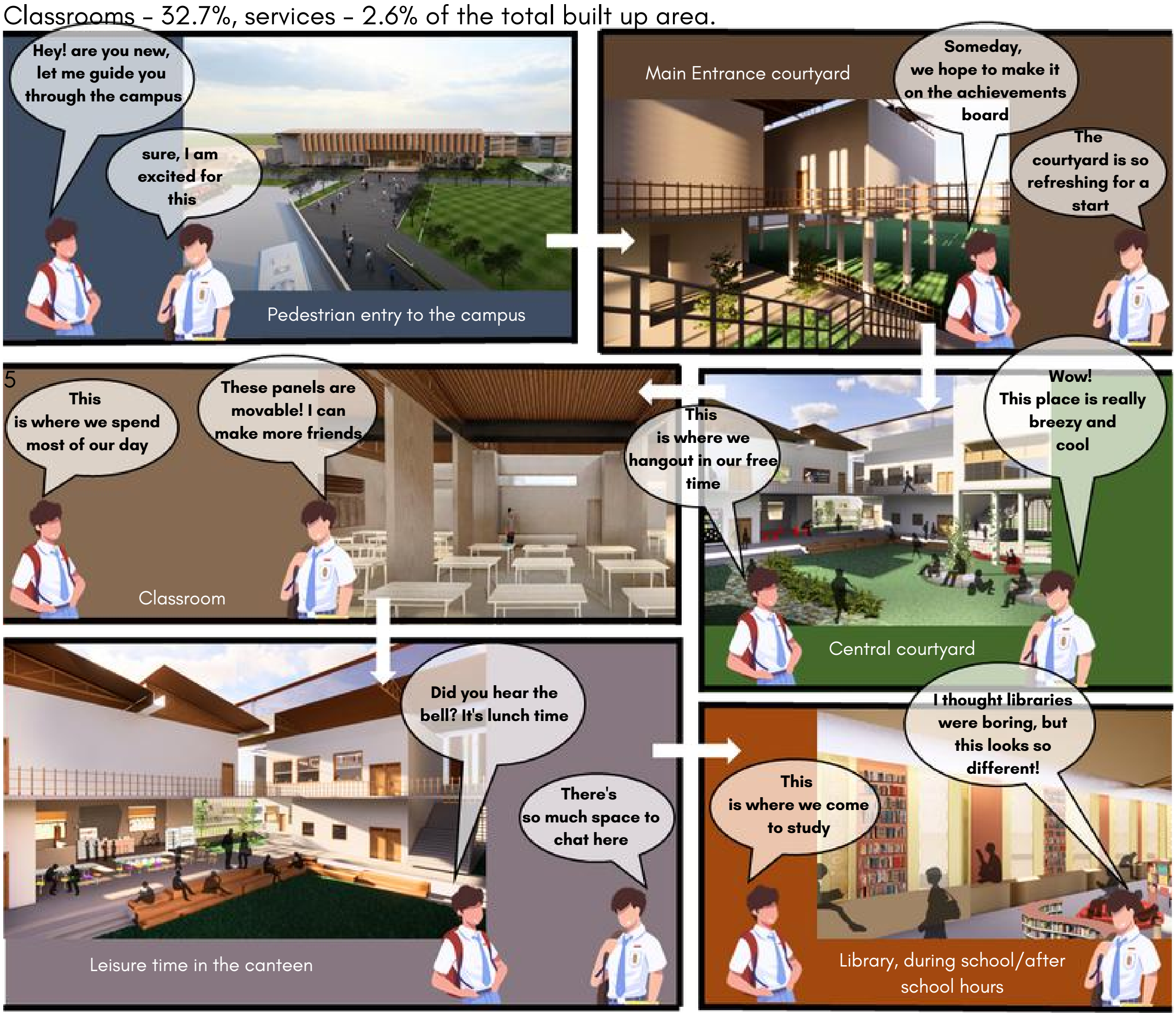
Courtyard

Figure 10.6.g: Section of the building



CIRCULATION

For ease of circulation around campus, IPS flooring is combined with coloured additives. Each colour used is specific to its purpose as shown in the legend. Hence this design feature helps the end-user to easily navigate to spaces within the site. 26% of the total built up is dedicated for circulation. Classrooms - 32.7%, services - 2.6% of the total built up area.



END USER EXPERIENCE

Figure 10.6.h: User experience

10.7 AFFORDABILITY

STRATEGIES USED TO OPTIMIZE COSTS

CAPEX

Optimizing Building Height and loads

85% ↓ in Foundation Costs

Due to the decrease in building height and increase in ground cover, we were able to use an isolated footing system as the loads reduced instead of pile foundations which were necessary in the base case due to a high water table.

Using local materials for hardscaping

75% ↓ in Hardscaping Costs

Reducing the amount of hardscaped area as well as the use of locally sourced materials like mosaic flooring and paver blocks.

Using locally available materials

38% ↓ in Wall Costs

Using materials like Bamboo and Zerund Bricks which are available locally, hence reducing transportation costs as well as feeding into the local economy.

Optimizing Water Consumption

60% ↓ in Water Storage Costs

Reducing the water consumption from 45 lcpd to 17 lcpd, which reduces the sizes of the Overhead and Underground tanks.

Reduction in Furnishing Costs

65% ↓ in Furniture Costs

Using our innovative Earthquake protection desks as opposed to standard school furniture.

OPEX

Energy Efficient Equipment

35% ↓ in Energy Costs

Replacing standard equipment with energy effiencient systems that are low maintenance, hence reducing the operation and maintenance costs over time and reducing energy consumption.

Low Maintenance Materials

38% ↓ in Wall Maintenance Costs

Incorporating materials like Zerund bricks for walls and epoxy flooring, which are low maintenance and also have a low carbon footprint.

Optimizing usage of Fuel

11% ↓ in Fuel Costs

Setting up a small biogas plant in order to fulfil the fuel requirements for the kitchen.

Base Case Cost - Rs 38,100 / sqm

Design Case Cost - Rs 33,100 / sqm

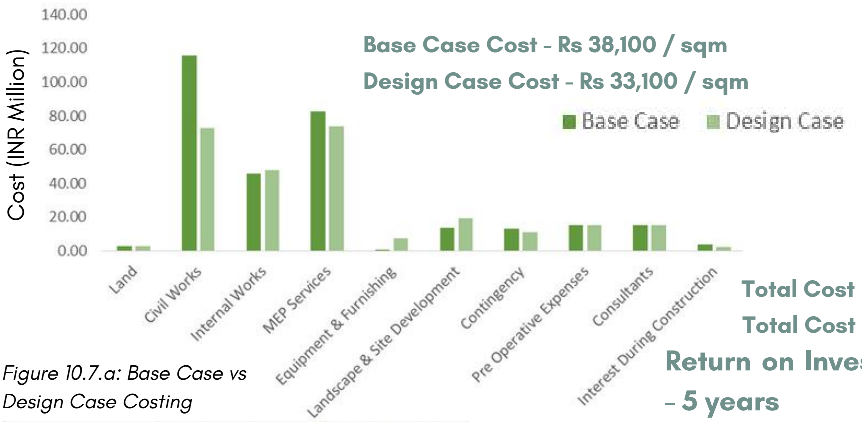


Figure 10.7.a: Base Case vs Design Case Costing

Total Cost Base Case - 307.32 INR Million

Total Cost Design Case - 266.65 INR Million

Return on Investment for Efficient Equipment - 5 years

	Amount Spent (INR Million) - Base Case				Amount Spent (INR Million) - Design Case		
	Year 1	Year 2	Year 5		Year 1	Year 2	Year 5
Maintenance & Repair Costs	3.07	6.14	12.28		2.68	5.36	9.21
Elecrical Supply Costs	3.6	3.6	3.6		0	0	0
Water Supply Costs	2.9	2.9	2.9		0	0	0
Sum	9.57	12.64	18.78				
Total Amount Invested in Efficient Systems	40.4						

Period	0	1	2	3	4	5	6	7
Cash Inflow (INR Million)		9.57	12.64	15.71	18.78	18.78	18.78	18.78
Cash Outflow (INR Million)	(40.40)	(2.68)	(5.36)	(8.04)	(8.04)	(8.04)	(8.04)	(8.04)
Net Cash Flow	(40.40)	6.89	7.28	7.67	10.74	10.74	10.74	10.74
Cumulative Cash Flow	(40.40)	(33.51)	(26.23)	(18.56)	(7.82)	2.92	13.66	24.40
Discounted Present Value	(40.40)	(31.03)	(24.29)	(17.19)	(7.24)	2.70	12.65	22.59

Discount Rate	8%
Internal Rate of Return (IRR)	2.18%
Payback Period (years)	4.67

Detailed list of efficient equipment used mentioned in the Appendix pg 64

Table 10.7.1 No of years taken to regain money spent on energy/water/carbon saving equipment in Design Case – 5 years

Table 10.7.1 shows the Return on Investment for additional features added in the design case over the base case. The cash inflow row shows the sum of Maintenance, Electrical and Water costs for the base case, which are inflows for our proposed case as it is a net zero energy and water building. The cash outflow row shows the capital cost in year 0, as well as the maintenance cost for the design case each year. The payback period for the additional costs is **5 years**. The payback period for the entire investment in the building, including loans paid is **35 years** (detailed calculations on pg 64). This implies that the building pays for itself within its lifetime (50 years), while continuing to generate income for the remaining time. This does not include the cash infows of the project partner (eg. fees) or outflows (eg. salaries).

Costing Summary shown in Appendix. (pg 65) Detailed costing sheet attached separately.

LIFE CYCLE COSTING - STP

Base Case - Conventional STP
Capital Cost (INR Million) - 1.4
Life Cycle Cost (INR Million) - 4.71

Design Case - ECO STP
Capital Cost (INR Million) - 1.75
Life Cycle Cost (INR Million) - 2.78

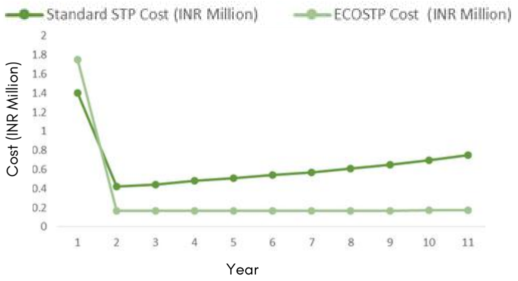


Figure 10.7.b: Life Cycle Costing - STP

LIFE CYCLE COSTING - WALLS

Base Case - AAC Blocks (100 cu.m)
Capital Cost (INR Million) - 0.88
Life Cycle Cost (INR Million) - 3.09

Design Case - Zerund Bricks (100 cu.m)
Capital Cost (INR Million) - 0.48
Life Cycle Cost (INR Million) - 0.72

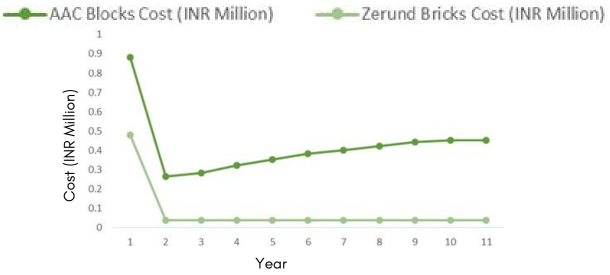


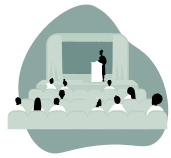
Figure 10.7.c: Life Cycle Costing - Wall Material

GREEN FINANCING OPTIONS - ASSAM GREEN BUDGET 2022-23

Scheme	Output	%	Budget (Lakhs)
Popularisation of Science- District and State Level National Children's Science Congress	Developing scientific and technological temperament among school students through school based solution oriented projects targetting specific problems of the society	-	-
Research and Development	Developing Research activities and facilities, human resource development and transferring technology derived from Research for field application and commercialization.	100	54
Implementation of 1000 MW Solar Power Plants across the State under Mukhyamantri Soura Shakti Prakalpa	Implementation of Solar Plant	100	450

Table 10.7.3 Green Financing Options that could potentially be used for the building
Source : Government of Assam Green Budget 2022-23

ADDITIONAL INCOME STREAMS - Renting out services



MPH (AC, 800 pax)
Rent - Rs 10000/day

Football Field (11 v 11)
Rent - Rs 250/hr

Basketball Ground (Full Court)
Rent - Rs 100/hr

Tennis Court
Rent - Rs 150/hr

10.8 INNOVATION

ACOUSTIC PANELS

Idea: Encourage and allow collaborative learning and engagement of students with sufficient sound-absorbing materials and minimize sound leakages.

Problem: Readymade acoustic partition walls are expensive to install. The materials used can be substituted with locally sourced materials having good sound absorption qualities.

Solution: The components are meticulously designed and built from scratch. They are locally sourced materials such as bamboo mats, jute fibres, rice husk boards and aluminium frames. According to the research report EduARCHsia 2019, bamboo mat cladding has an absorption coefficient of 0.5. Jute fibres are used for sound insulation.

Market: This product can be scalable since it is cost-effective and functions as a sound absorber.

Cost and benefits: The price has decreased overall because the components were constructed from scratch and used locally available materials like rice husk and bamboo mats.

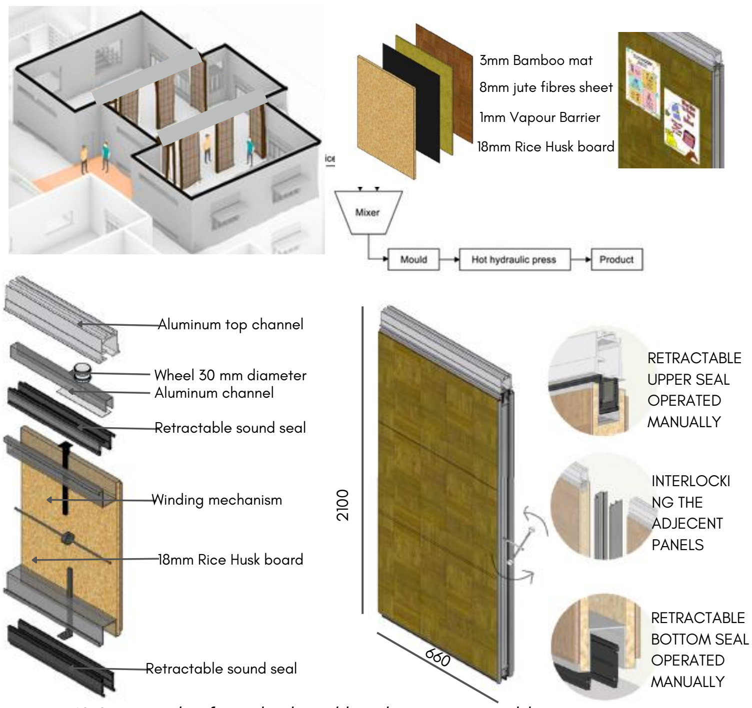


Figure 10.8.i: Details of rice husk and bamboo mat movable acoustic partition walls

Refer appendix 12.17, pg .no 74 for costing calculation

HYDRAWATT IMPULSE TURBINE

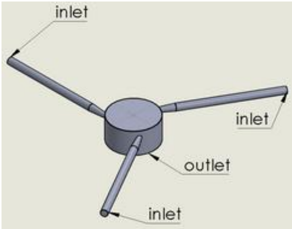


Figure 10.8.a: Nozzle and Casing

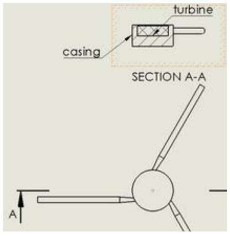


Figure 10.8.b: Sectional view

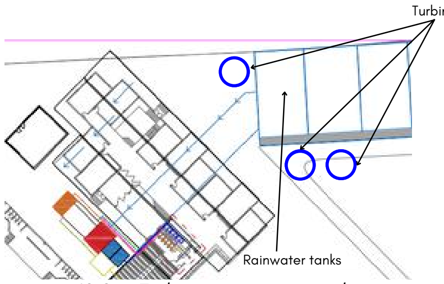


Figure 10.8.c: Turbine Integration with rainwater harvesting tank

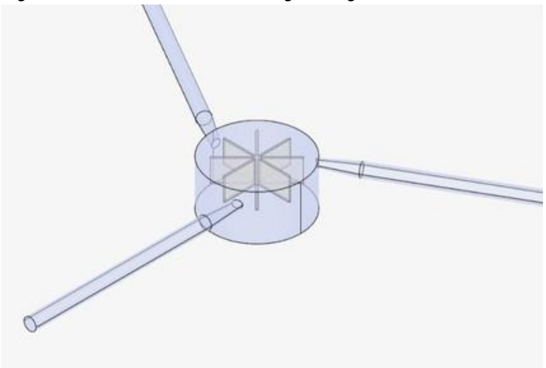


Figure 10.8.d: Impulse Turbine

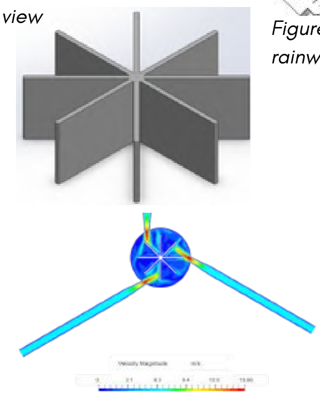


Figure 11.8.e: Simulation results of impulse turbine

Metrics:

1. Diameter of casing: 0.8m
2. Height of casing: 0.41m
3. Height of turbine: 0.2m
4. Diameter of turbine shaft: 50mm
5. Radius of turbine blades from axis of rotation: 0.3m
6. Number of blades: 8
7. Thickness of turbine blades: 20mm

1. Idea: Our site experiences an immense amount of annual rainfall, and as mandated by the government, a rainwater harvesting tank has to be constructed. Our product couples with the harvesting tank to produce energy, irrespective of whether the water is being collected on-site or being used to recharge the water table. Compared to a water vortex, which requires a large flow rate, this turbine provides greater energy per litre of water. Detailed power calculations (pg.72) along with comparison between the water vortex and the impulse turbine (pg.73), can be found in the Appendix.

2. Problem: High percentage of cloud cover in the site and an abundant amount of rainfall, which can be harvested and used for the generation of renewable energy using the impulse turbine, instead of letting it run off.

3. Solution: The impulse turbine converts hydraulic energy into electricity and it can be readily implemented. It is mostly made of glass fibre (turbine and casing), while the pipes are made of PVC, which are antibacterial, antifungal and highly corrosion and abrasion resistant, which results in low maintenance, long life and no maintenance while producing a considerable amount of usable energy. Ease in manufacturing and assembly is indicated by the following factors:

i) Moulding: A set of moulds can be used for large-scale production of components, taking full advantage of economies of scale. Moulding is one of the cheapest forms of manufacturing.

i*i) Standard size and shape:* Customization requires additional infrastructure and is economically intensive. Different capacities can be accommodated by installing multiple turbines coupled to a common shaft to increase the net torque.

iii) Space-efficient design: The total diameter of the assembly is 0.8m, while the net height/depth is around 0.4m. Thus, it can easily be accommodated even in a domestic setting.

4. Market: Areas with high rainfall and steeper terrains are the target market. Since the turbine is mostly maintenance-free and small in size, areas with low rainfall can use a smaller generator to compensate for the low speed of rotation. The main marketing strategy consists of free installation in domestic and professional settings as a test, and using the results obtained as evidence of its effectiveness to attract customers and assure them of its various benefits.

5. Costs and Benefits: The assembly would cost around Rs. 90,000 to produce (Rs.30,000 for the turbine and the rest for the generator, which is variable), while the maintenance cost would depend on the generator manufacturer. Since the turbine requires no maintenance, the OPEX is very low. Although rainwater harvesting has been made mandatory by governmental agencies, our product would be able to reduce expenditure on electricity, indirectly reducing the total amount of carbon emitted from burning fossil fuels, reduce dependency on solar panels, which have a greater cost/energy ratio, while simultaneously incentivizing people to implement the same.

Name: SAFETY PRISM (Earthquake-resistant furniture)

Idea: A bench with a top that can be rotated 240 degrees to convert to the most stable form of geometry—a triangle— during an earthquake to transform into a protective shield against falling objects. It is immediately accessible and is a quick response during a disaster.

Problem: In earthquake-prone areas, buildings kill more than the earthquake itself due to falling objects, therefore, immediate protection can be provided by integrating a shield with the nearest contact, which is furniture. This can offer immediate protection from any objects falling vertically onto people.

Solution: Furniture that is ergonomically suitable for various ages that provides immediate protection from unforeseen falling objects. This is made from locally sourced materials as the legs are made up of bamboo (Bambusa Balcooa), the tabletop is made of bamboo plywood and joinery A is from welded steel, joinery B is bolted to bamboo.

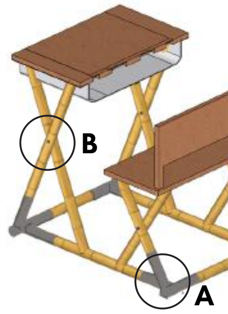
Market: Due to the Northeast region's annual seismic risk, it is possible to scale the furniture to all schools in earthquake-prone areas for the protection of the occupants in unforeseen and dangerous circumstances. It is possible to scale up because only the main members have to be replaced and it can be replaced with the locally available materials of that region and easily assembled.

Cost and benefits:

Base case: Furniture with steel structure, wooden tabletop and seating. Cost: Rs 5,000.

Design case: Bench made from Bamboo and steel joinery. Cost: Rs. 1600

This is completely dismantlable and can be packed compactly. The materials are locally sourced making it economical. Assembling and re-assembling is quick and joinery is very simple.



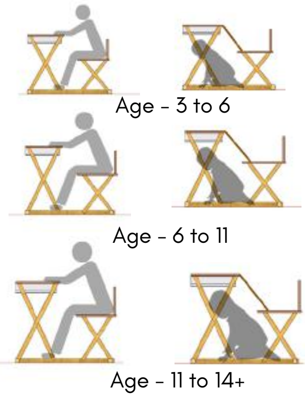
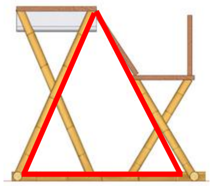
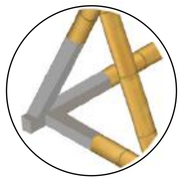


Figure 10.8.j: Sizes according to various ages



The triangle is formed when the table top is flipped

The table top can be flipped 240 degress



Steel joinery A connecting the bamboo structure

Completely dismantled On site assembly

Figure 10.8.k Earthquake shield bench

Refer appendix 12.17, pg .no 75 for WD drawings

FIGURE 10.8.L EARTHQUAKE SHIELD BENCH PROTOTYPE SCALE 1:1 STILL IN PROCESS

Name - BAH SHORON (Bamboo shelter/Partition walls)

Idea: A multi-functional panel that can serve both as a functioning student desk and an interior partition. Due to its modular design, it can be readily shifted and transferred to new locations as needed.

Problem: Although extra elements were introduced to make partition panels versatile, they still only serve one purpose.

Solution: Assam offers a wealth of locally produced, cost-effective, and low-embodied carbon materials including bamboo and jute. Having them weather resistant, they can withstand outdoor conditions, which suits the purpose of the partition panels.

Market: Since a majority of Assam's areas are prone to earthquakes and flooding, these panels can be used for patient interior hospital wards, outdoor refuges, and vaccination drives during emergencies.

Cost and benefits: By converting these partition walls into tables, children can stand up and work, which is good for their physical health. It can also be transformed into a roof, enticing children to spend time outside and giving them shade.

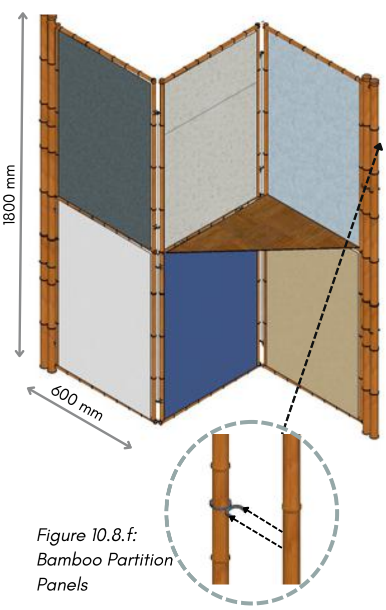


Figure 10.8.f: Bamboo Partition Panels

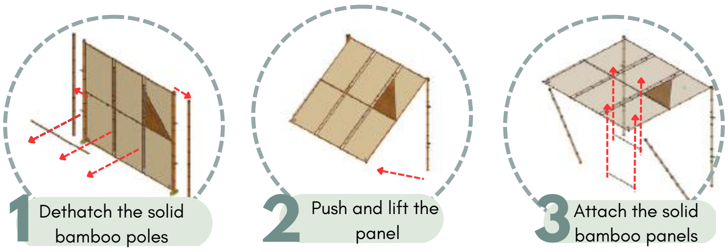
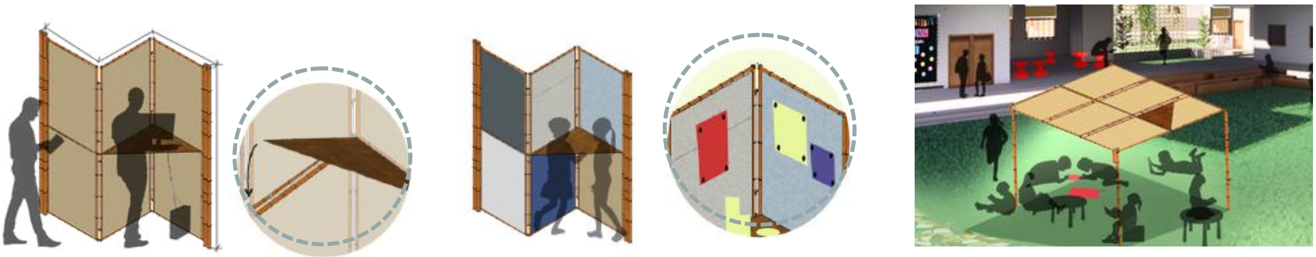


Figure 11.8.g: Bamboo partition panel construction

CIRCULAR BUILT UP SPACE

In addition to being utilised as a standard partition panel, the partition wall can be altered and used in a variety of spaces. The goal is to make it user-friendly and accessible to students. This gives the learning experience freedom in terms of location and use, rather than limiting it to a small, enclosed space.



A PRIVATE READING SPACE IN LIBRARY

HAVING MAGNETIC PANELS FOR DISPLAY

A SHELTER USED IN THE COURTYARDS TO SIT UNDERNEATH IT

Figure 10.8.h: Views showing various uses of bamboo partition panels

Refer appendix 12.17, pg .no 74 for costing calculation

10.9 HEALTH AND WELL-BEING

THERMAL COMFORT

Graph showing the various parameters for the climate of Nagaon .Comfort zone - 20°C to 25.5°C

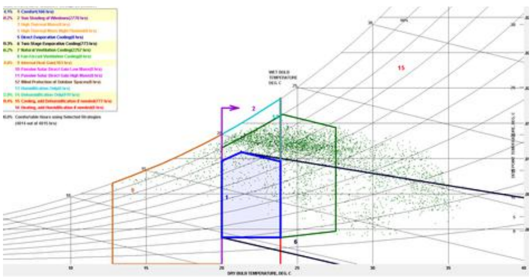
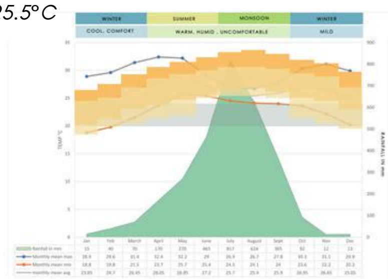


Figure 10.9.a: Psychrometric chart



Source: Climate Consultant
Figure 10.9.b: Graph generated from Mahoney's table

Assam has a humid subtropical climate according to Köppen-Geiger climate classification. Considering The relative humidity levels are >55%, heat & humidification have been taken care of through ventilation. Cooling and dehumidification for > 24°C, various strategies were used to achieve 100% comfortable hours

The IMAC (India Model for Adaptive Comfort) shows that there is a potential for utilizing favourable outdoor environmental conditions. We are opting for **16%** of our building area as mechanically ventilated (only in summer months) and **84%** of the building area is naturally ventilated throughout the year. Spaces such as MPH and seminar hall are made for mixed-mode operation. For about 8.4% of the operational period that is 84**%** of comfortable hours can be achieved through passive design and natural ventilation. Hence the building is designed to be a naturally ventilated building. According to IMAC, for naturally ventilated buildings, the 90% acceptability range is +2.4°C from the neutral temperature (20.5-28.5C) . All of the above mentioned results have been achieved as seen in the simulations. Summer months are mostly naturally ventilated, 16% of non-conditioned hours can be made comfortable by ceiling fans which bring down the temperature by 2-3°C. **Therefore, achieving 100% comfortable hours in the building.**

Operative temperature = (0.25 x DBT (30-day running mean) + 17.87

MONTHS	ACCEPTIBILITY RANGE	NATURALLY VENTILATED	
		MAX	MINIMUM
January	90%	24.69	19.9
February	90%	25.06	20.3
March	90%	26.59	21.83
April	90%	27.97	23.21
May	90%	28.72	23.96
June	90%	30.1	25.34
July	90%	30.51	25.75
August	90%	30.53	25.77
September	90%	30.3	25.54
October	90%	28.73	21.81
November	90%	27.94	21.02
December	90%	26.91	19.99

Table 10.9.1: Maximum and minimum temperature ranges with 90% acceptability Source : IMAC comfort tool

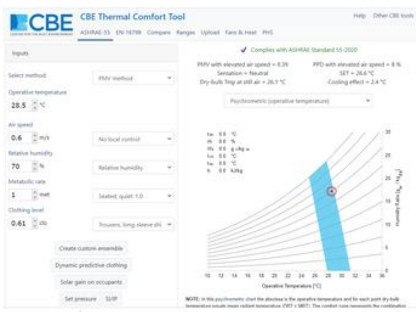


Figure 10.9.c: CBE Thermal Comfort Tool

By introducing an elevated air speed of 0.7m/s, the upper comfort threshold is further increased by 2.5°C as given by ASHRAE 55-2017 which is achieved through ceiling fans providing comfortable hours during unconditioned times. (Calculated using CBE Thermal comfort tool)

The use of materials which have low conductivity, envelope optimization, efficient Window-Wall Ratio (WWR) and natural ventilation have helped in decreasing the internal heat gain within the building.

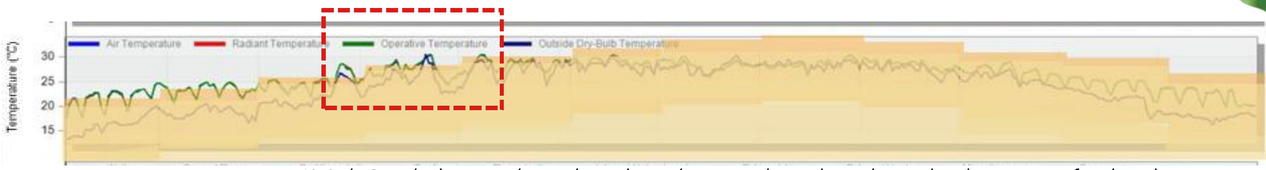


Figure 10.9.d: Graph showing thermal simulation(proposed case) overlay with adaptive comfort band

IMAC 90% acceptability   Elevated threshold (0.6m/s)

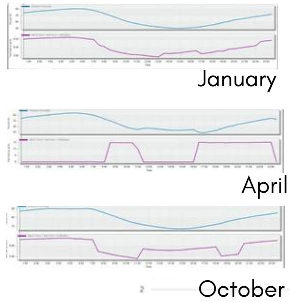
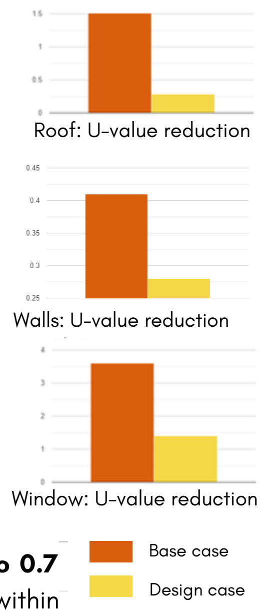
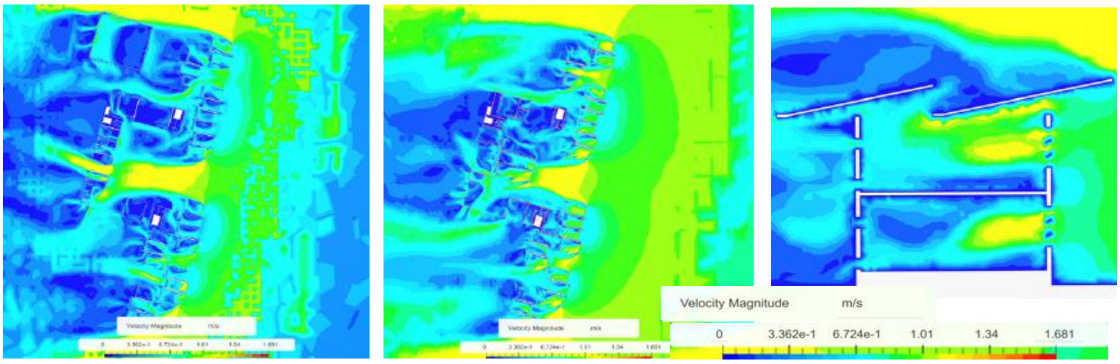


Figure 10.9.e: Relative humidity, total fresh air for July,
Refer to appendix 12.16 , page 69 for further monthly breakdown graphs

The envelope of the building was also optimized by using materials that have lower U-values to increase the thermal performance of the building so that the comfort conditions are achieved while also reducing the energy requirements of the building to maintain those conditions.



VENTILATION



Ground floor   First floor   *Figure 10.9.g: Wind Simulations   Source: Ansys*

The wind simulations show that the air speed achieved in the classrooms is between **0.3 m/s to 0.7** m/s without fan-forced ventilation. Therefore with ceiling fans and aided ventilation, air speeds within the building can be increased further to improve thermal comfort and reduce humidity. The design lets the wind pass through it rather than resist it, this results in letting in enough wind for the comfortable usage of the classrooms. The sill height has been maintained in order with the height of the tables.

ORIENTATION

East-West orientation increases ventilation and daylight access. The stack effect can also help regulate indoor temperature and thermal comfort. In winter, the warm air rising inside the building can help keep the upper floors warmer, reducing the need for heating and improving comfort for occupants.

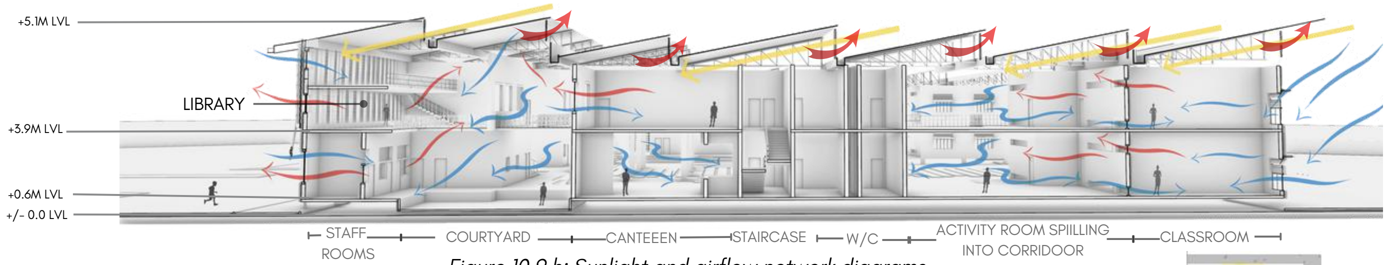


Figure 10.9.h: Sunlight and airflow network diagrams

VISUAL COMFORT (DAYLIGHTING)

The light cycle of the sun has a powerful effect on the circadian clock, sleep, and alertness. Utilizing the sunlight from the northern side, the first floor is roofed with a north-light truss to optimize the amount of daylight entering the building and improve visual comfort.

Simulations of UDI (in energy performance page no.17)in classrooms prove that the classrooms are daylit for **75%** of the year which means for 1650 hours of 2200 hours, the building is 100% daylit, not only reduces lighting loads but also make students more active.

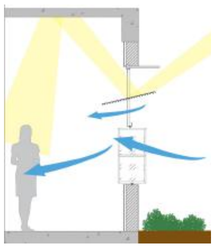


Figure 10.9.i: Section northern window

INDOOR AIR QUALITY

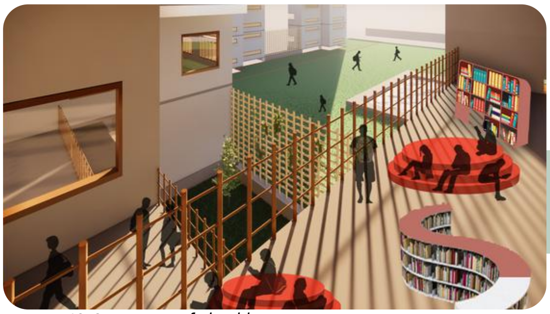
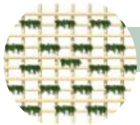


Figure 10.9.j: View of the library



- Use of courtyards in spaces like library.
- This contributes in a more productive indoor environment.

Figure 10.9.k: View of the central courtyard

- Creating more interactive spaces for the better mental growth of the students.
- Using an element of biophilia on the jali results in a much cooler microclimate.

Figure 10.9.m: View of self-shaded spaces due to staggering of the building

- To ensure outdoor comfort, shaded seating under trees have also been created.

STRATEGIES TO REDUCE THERMAL SHOCK

- Semi-covered transitional spaces have been incorporated throughout the building to reduce thermal shock.
- Due to the staggering of the building, self-shaded niches and pockets have been created which act as areas where students come together.
- They also have a visual connection with the sports area of the campus.

- Made up of bamboo , which is sustainable and locally available.
- Prevention of harsh south light entering the transition spaces.

Figure 10.9.l: View of the smaller courtyard and staircase between classrooms

Golden Pothos

Bamboo Palm

Aloe Vera

Reference: picturethisai.com

- Indoor plants perform various functions such as reducing the moisture content and dehumidification while also maintaining indoor air quality by purifying the air from particles such as formaldehyde and xylene. *Reference: abanahomes.com/best-air-purifying-plants/*
- Indoor air quality has also been maintained by reducing the VOC contents by using lime plaster with natural pigment, avoiding painting the internal walls as compared to base case cement paint, and Zerund bricks reducing carbon emissions by 50%.

SPACES	AIR EXCHANGES PER HOUR (AS PER NBC)	ACH ACHIEVED
CLASSROOMS	5 TO 7	17
LABORATORIES	6 TO 15	14
LIBRARY	3 TO 5	5
HOD	6 TO 20	20
CANTEEN	8 TO 12	9
TOILETS	6 TO 10	7

Refer Appendix 12.16 ,pg. no 71 for calculations

Table 10.9.2: Air Exchanges achieved

- A sufficient number of air exchanges have also been ensured in key spaces of the building to have constant supply of fresh air

ACOUSTIC COMFORT

- The indoor movable acoustic partition walls have a retractable upper and bottom sound seal, and sandwiched bamboo mats and jute fibres and rice husk have good sound absorption, maintaining a 40 - 45 dD noise level indoors.

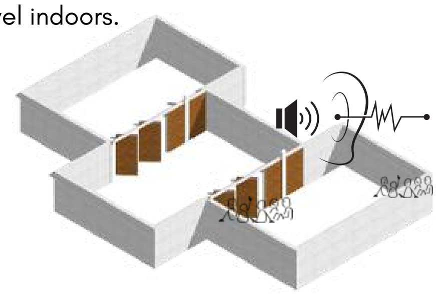


Figure 10.9.n: Partition walls for acoustic comfort

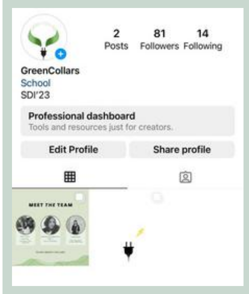
- The National Highway 37 abutting the site causes a background noise level that peaks at 98.2dB and an average of 60.7 dB. The rammed earth compound wall reflects the noise from the highway, green buffer further shields the site from outdoor noise.

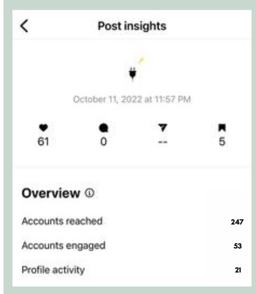
10.10 VALUE PROPOSITION

PITCH TO PROJECT PARTNER

EKĀGRA is a net zero positive-energy, net zero-water building for Gyandeep foundations DPS school, Nagaon, Assam. The school has an area of 8072 sqm, proposed to host 1800 students and 200 staff with the possibility of future expansion catering to the students of Nagaon and nearby villages.

SOCIAL MEDIA





Use of Zerund bricks for walls giving an EC reduction of 124%

An efficient rainwater harvesting system has been worked out to achieve net zero water

Net +ve energy 8410 KWh/yr

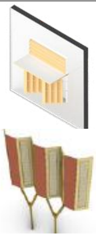
Energy and water efficient fixtures

earthquake furniture design

jute partition walls

Day-lit - 98% of operational hours

Optimizing sunlight entering the space to induce natural lighting. The roof also provides space for solar panels. Individual windows have been designed according to the shading angles.



south side facade design

EC reduction = 77%

Net-Zero waste

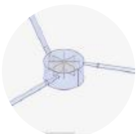
Use of biogas for cooking

Helps students learn about NZEBs and sustainability and the processes involved

Incorporating vernacular materials, and methods of construction of Assam by using bamboo - availability of high-quality bamboo. Helping local workers, construction, craftsman, economy. The circular economy of materials reduces greenhouse gas emissions. Planting bamboo in the unbuilt part of the site.

The project acts as a Community Resilience center during disasters, mainly the MPH which has been tested and simulated for earthquake.

Multi-resilience structure



IMPULSE TURBINE
Reducing loads and power consumption and fulfilling the energy requirements using the impulse turbine system and solar panels.

Energy generated through Solar PV is 222490 kWh

Decrease of 30% in the OPEX and 12% in the CAPEX

Encouraging use of local materials for school supplies-and equipment -like furniture,bags, panels,etc.Furniture are dismantlable, hence convenient and cost effective to the users.

Interiors are designed to provide **100% thermal comfort** and withstand high humidity by creating breakout spaces and courtyards, use of indoor plants, organic farming improving the health and mental wellbeing of the users.

The proposed cost of construction is Rs. 266.65 INR Million which is 12% decrease from the base case cost of construction which is Rs.307.32 INR Million

Our proposed building earns 81 points which come under the 4 star GRIHA

Figure 10.10.a: Project partner pitch

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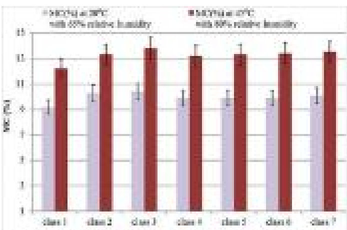
asali bali engineers bamboo structure capable of covering 545m2

every detail of the construction, and particularly its connections, have been carefully designed by a senior



Mechanical Properties of Bamboo Through Measurement of Culm Physical Properties...

Bamboo fibers with high mechanical properties can be a sustainable alternative to synthetic fibers for application in fiber reinforced polymer composites....

Acoustical Abilities of Woven Bamboo to Absorbing and Transmitting of the Sound |...

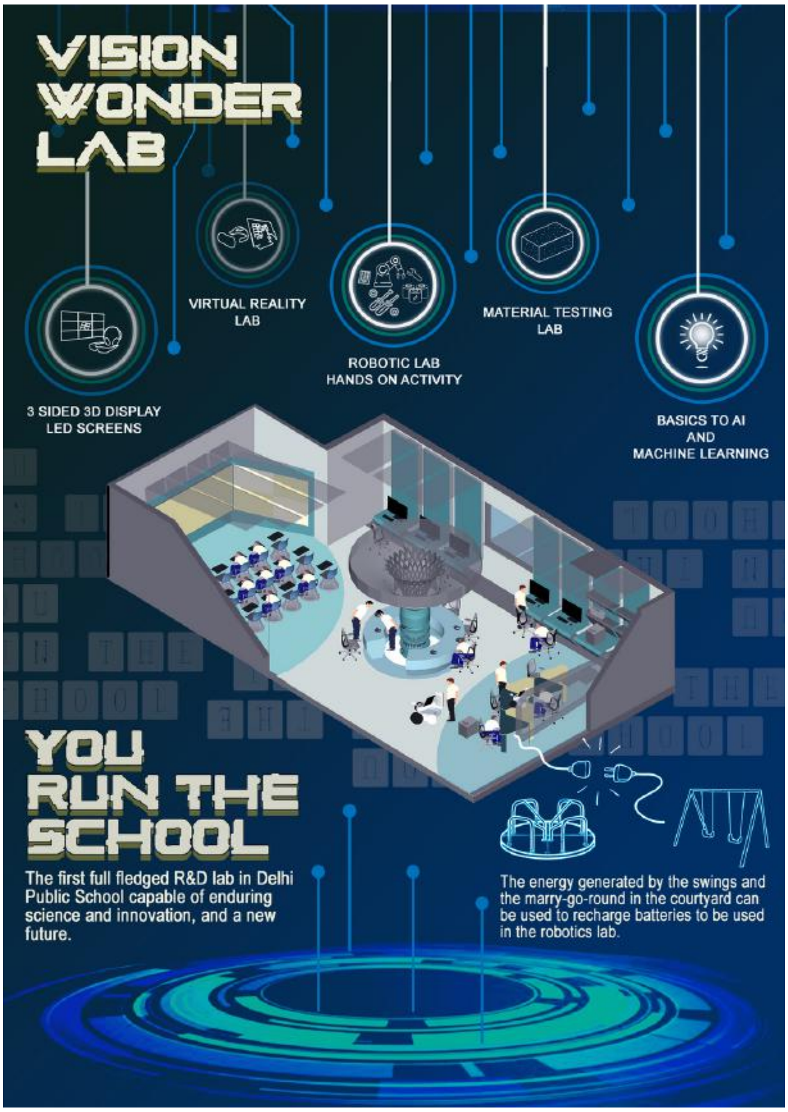
Request PDF | On Jan 1, 2020, Suyatno and others published...

12. APPENDIX

12.1 POSTER 1

Appendix figure 1: School poster

12.2 R&D BLOCK



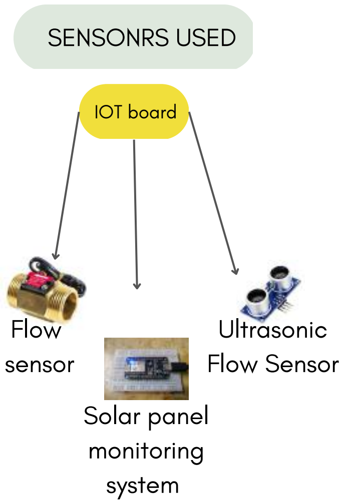
Appendix figure 2: R&D Block poster

Appendix Figure 3: Energy board

Each class's energy consumption is displayed and by the end of the month the class which saved the most energy is rewarded.

ENERGY DAILY DISPLAY

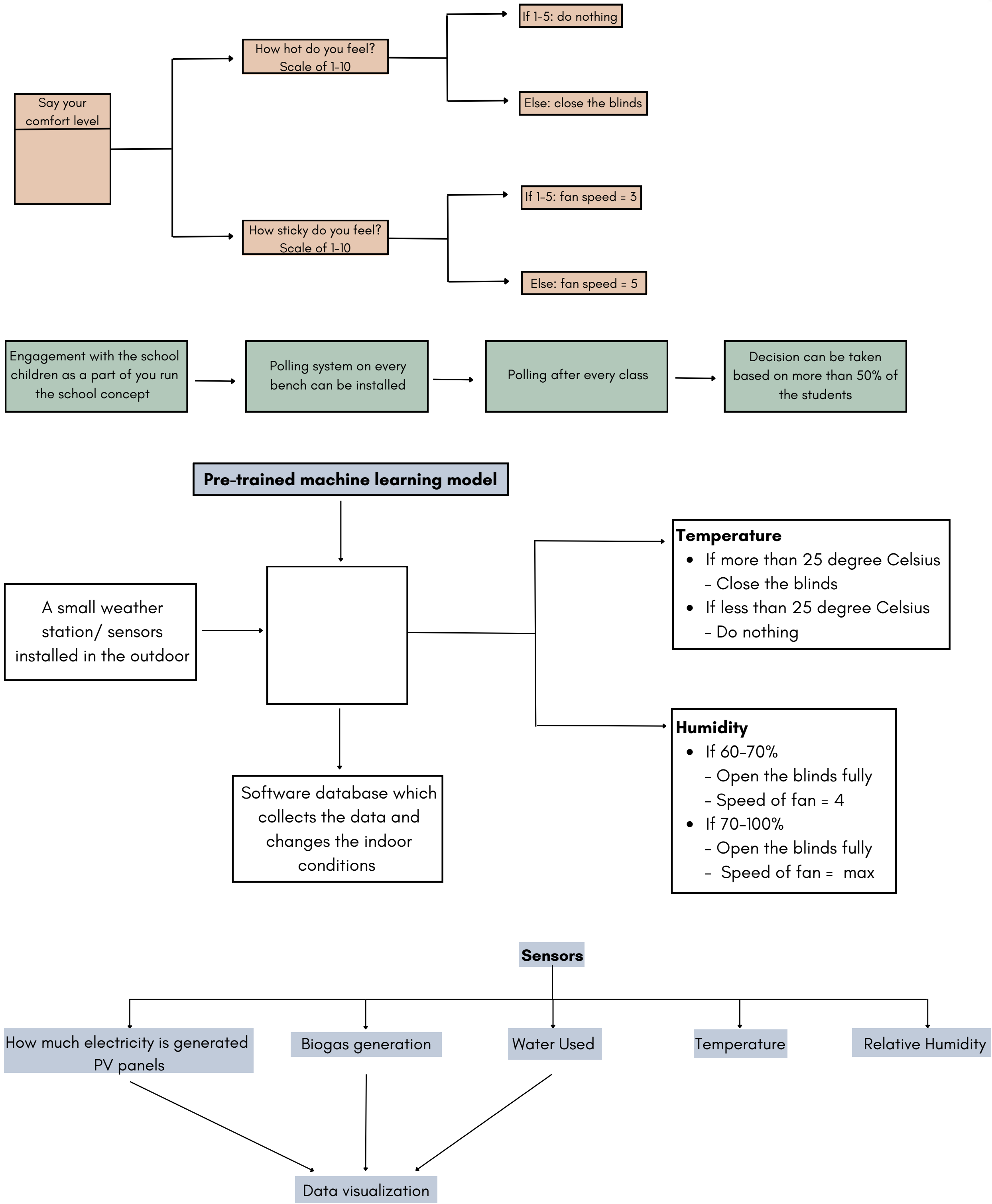
The UX/UI interface is user-friendly and visually appealing, with easy-to-understand data that is accessible at a glance.
It includes a dashboard that displays the current solar energy, water generation, biogas and waste generation along with a graph that shows the historical data.



There are a total of two different visual panels one that shows the energy status of the class and the other one that is an interactive screen which takes input from the students about their comfort level and gives them strategies to optimise their thermal comfort and suggests them with strategies

	8:15 - 9:00	9:00 - 9:40	9:40 - 10:25	10:25 - 10:35	10:35 - 11:20	11:20 - 12:05	12:02 - 1:05	1:05 - 1:40	1:40 - 2:25
MON									
TUE				B			B		
WED				R E			R E		
THU				A			A		
FRI				K			K		
SAT									

Appendix figure 4: Time table



Appendix figure 4: Time table

12.3 DETAILED BUILDING AREA PROGRAM

S.No	Function	Description	(Per Unit)	Unit)	Units	(sqm)	Conditioning	Occupancy	Total occupancy
1	Classrooms	Pre school	30	60	8	480	Non - Conditioned	30	240
		Junior	40	60	12	720	Non - Conditioned	40	480
		Middle	40	60	12	720	Non - Conditioned	40	480
		High	40	60	14	840	Non - Conditioned	40	560
2	Staff rooms		12	30	4	120	Non - Conditioned	12	48
3	Canteen	Jr & middle	480	100	1	100	Non - Conditioned	480	480
		High	280	50	1	50	Non - Conditioned	280	280
4	Infirmary		7	20	1	20	Conditioned	7	7
5	Labs	Physics	25	70	1	70	Non - Conditioned	25	25
		Chem	25	70	1	70	Non - Conditioned	25	25
		Bio	25	70	1	70	Non - Conditioned	25	25
		Comp	25	70	2	140	Non - Conditioned	25	50
6	Art Room		40	70	1	70	Non - Conditioned	40	40
7	Activity Room		40	60	3	180	Non - Conditioned	40	120
8	Library	Large Block	2000	300	1	300	Non - Conditioned	2000	2000
9	Principal		2	20	1	20	Conditioned	2	2
10	HOD		2	15	4	60	Non - Conditioned	2	8
11	Admin		50	60	1	60	Non - Conditioned	50	50
12	Storage			15	4	60	Non - Conditioned		0
13	MPH		1000	800	1	800	Conditioned	800	800
14	Lobby		20	30	1	30	Non - Conditioned	20	20
15	Staff Commons		50	20	1	20	Non - Conditioned	50	50
16	Printing Room			10	4	40	Non - Conditioned		0
17	Kitchen		10	30	1	30	Non - Conditioned	10	10
18	Seminar Hall		400	200	1	200	Conditioned	400	400
19	R&D block		25	150	1	150	Conditioned	25	25
20	Toilet Blocks			52.5	8	420	Non-conditioned		
21	Showers			10	1	10	Non-conditioned		
22	Changing Rooms			10	1	10	Non-conditioned		
23	Circulation					2000	Non-conditioned		
	Services								
1	Pump room			40	1	40	Non-conditioned		
2	STP			35	1	35	Non-conditioned		
3	Treated water tank			10	1	10	Non-conditioned		
4	Domestic water tank			10	1	10	Non-conditioned		
5	Rain water tank			10	1	10	Non-conditioned		
6	Fire tank			15	2	30	Non-conditioned		
7	OHT tank			3	2	6	Non-conditioned		
8	Hub/Server Room			16	1	16	Conditioned		
9	Electrical Room			10	1	10	Conditioned		
10	Panel Room			30	1	30	Non-conditioned		
11	LV Room			15	1	15	Non-conditioned		
	Total Built Up Area					**8072**			
	Student Zone					5010			
	Office Zone					380			
	General					2682			
	Conditioned Area					1216			
	Non-Conditioned Area					6856			
	Open Areas								
1	Foot ball ground			6828	1	6828			
2	Basketball			415	2	830			
3	Tennis			315	1	315			
4	Swimming Pool			416	1	416			
5	Play Ground			400	1	400			
6	Parking			600	1	600			
7	HT Yard + Transformer			50	1	50			
8	DG Yard			60	1	60			
	Total Open Areas					**9499**			

Student zone
office zone
conditioned
non conditioned

Appendix table 1: Detailed building area program

12.4 COMPARATIVE AREA PROGRAMME

BASE CASE	NO	TOTAL AREA	DESIGN CASE	NO	TOTAL AREA
Classrooms	42	2362	Classrooms	46	2640
Staff Rooms	7	110	Staff Rooms	4	120
Canteen	1	100	Canteen	2	150
Infirmary	1	30	Infirmary	1	30
Labs	4	200	Labs	5	350
Activity Room	4	280	Activity Room	3	180
Admin Block		240	Admin Block		270
MPH	1	800	MPH	1	800
Lobby	1	30	Lobby	1	30
Toilets	3	414	Toilet Blocks	8	420
Circulation		2000	Circulation		2100
			Art Room	1	70
Library	1	300	Library	1	300
			Seminar Hall	1	200
Kitchen	1	30	Kitchen	1	30
			RnD	1	150
			Showers	1	20
Services		200	Services		212
		7096			**8072**

Appendix table 2: Comparative area

12.5 ARCHITECTURAL DRAWINGS

Appendix figure 5: Ground level plan

Appendix figure 6: First level plan

12.6 ENGINEERING DRAWINGS

Appendix figure 7: Column grid layout

SOLID WASTE MANAGEMENT

CATEGORY	MATERIAL	ACTION
NON-BIODEGRADABLE	PLASTIC	Plastic embedded lightweight brick manufacturing
	PVC WASTE(from building)	
BIO-DEGRADABLE WASTE	FOOD	Composting
	LEAVES	
RE-CYCLABLE WASTE	PAPER	Material collected could be used to create innovative products, thus inducing the knowledge of sustainability in students .
	CARDBOARDS	
	PAPER TUBE	
BIO - WASTE	SANITARY PADS	Incinerator
	MEDICAL WASTE FROM INFIRMARY	

Appendix table 3: Solid waste management

* Rajamanikam Ramamoorthy,Gopalsamy Poyyamoli1, Sunil Kumar(Solid and Hazardous Waste Management Division, Nehru Marg, Nagpur-440 020, India);"ASSESSMENT OF SOLID WASTE GENERATION AND MANAGEMENT IN SELECTED SCHOOL CAMPUSES IN PUDUCHERRY REGION, INDIA"-2019; Published in Environmental Engineering and Management Journal

Waste Category	Waste generated(*) (Kg/capita/day)	Total Waste generated (Kg/day)
FOOD	0.036	72
PAPER	0.030	60
PLASTIC	0.007	14
BIO MEDICAL	0.001	2
LANDSCAPE	0.01	20
OTHERS	0.003	6

Appendix table 4: Quantity of Solid waste generation in school per day

12.7 ENERGY CALCULATIONS OF DESIGN CASE

STUDENT ZONE							
APPLIANCE	**Quantity**	**Wattage (W)**	**No.of hours / day**	**Diversity factor**	**Energy consumed daily (Whr)**	**No.of days**	**Energy consumed annually (Whr)**
Smart board	46	220	5	0.95	48070	243	11681010
Laptops	0	150	5	0.95	0	243	0
Computers	65	65	5	0.95	20068.75	243	4876706.25
Printers	8	35	5	0.95	1330	243	323190
Projectors	4	500	5	0.95	9500	243	2308500
Microwave	2	950	5	0.95	9025	243	2193075
Induction	2	1500	5	0.95	14250	243	3462750
Coffee machine	0	1000	5	0.95	0	243	0
Ceiling fans	195	34	5	0.95	31492.5	243	7652677.5
6A Sockets	209	100	5	0.95	99275	243	24123825
16A Sockets	14	1000	5	0.95	66500	243	16159500
PHE	1	15	5	0.95	71.25	243	17313.75
Lifts	2	3500	8	0.95	53200	243	12927600
Exhaust fans	14	16	8	0.95	121.6	243	29548.8
CC Cameras	78	5	24	0.95	8892	243	2160756
Refrigerator	4	28.4	24	0.95	2590.08	243	629389.44
Fire alarm	85	45	24	0.95	87210	243	21192030
Water purifier	8	36	24	0.95	6566.4	243	1595635.2
Jockey pumps	1	365.52	24	0.95	8333.856	243	2025127.008
Hydrant pumps	1	365.52	24	0.95	8333.856	243	2025127.008
STP pumps	1	365.52	24	0.95	8333.856	243	2025127.008
LUNCH TIME							
Smart board	46	220	1	0.2	2024	243	491832
Laptops	0	150	1	0.2	0	243	0
Computers	65	45	1	0.2	585	243	142155
Printers	4	35	1	0.2	28	243	6804
Projectors	4	500	1	0.2	400	243	97200
Microwave	2	950	1	0.2	380	243	92340
Induction	2	1500	1	0.2	600	243	145800
Coffee machine	0	1000	1	0.2	0	243	0
Ceiling fans	195	34	1	0.2	1326	243	322218
6A Sockets	209	100	1	0.2	4180	243	1015740
16A Sockets	14	1000	1	0.2	2800	243	680400
						Total energy	**120403377**
OFFICE ZONE							
APPLIANCE	**Quantity**	**WATTAGE (W)**	**No.of hours / day**	**Diversity factor**	**Energy consumed daily (Whr)**	**No.of days**	**Energy consumed annually (Whr)**
Laptops	48	65	8	0.95	23712	243	5762016
Computers	19	65	8	0.95	9386	243	2280798
Printers	8	35	8	0.95	2128	243	517104
Coffee machine	6	1000	8	0.95	45600	243	11080800
Cleaning	4	500	8	0.95	15200	243	3693600
6A Sockets	124	100	8	0.95	94240	243	22900320
16A Sockets	4	1000	8	0.95	30400	243	7387200
						Total energy	53621838
LUNCHTIME							
Laptops	48	65	1	0.25	780	243	189540
Computers	19	65	1	0.25	308.75	243	75026.25
Printers	8	35	1	0.25	70	243	17010
Coffee machine	6	1000	1	0.25	1500	243	364500
Cleaning	4	500	1	0.25	500	243	121500
6A Sockets	124	100	1	0.25	3100	243	753300
16A Sockets	4	1000	1	0.25	1000	243	243000
						Total energy	1763876.25
TIME BEFORE SCHOOL							
Laptops	48	65	1	0.45	1404	243	341172
Computers	19	65	1	0.45	555.75	243	135047.25
Printers	8	35	1	0.45	126	243	30618
Coffee machine	6	1000	1	0.45	2700	243	656100
Cleaning	4	500	1	0.45	900	243	218700
6A Sockets	124	100	1	0.45	5580	243	1355940
16A Sockets	4	1000	1	0.45	1800	243	437400
						Total energy	3174977.25
					Total equipment power consumption		178964068.5
							178964.0685

Appendix table 5: Energy calculations of design case

HVAC	1	925	9	1	16650	365	6077250
							6077.2
DOAS SYSTEM							5088250
							5088.2
INTERIOR LIGHTING							18245995.2
							18245.9952
EXTERIOR LIGHTING							2000000
							2000
WATER HEATING		(Heat pump)			8000	243	1944000
							1944
IOT SYSTEM		30	24		720	243	174960
							174.96
R&D Block							**1500.28**
						Total	**213994.7037**
						Area	8072
						EPI	**26.51074129**

Appendix table 6: Energy calculations

Lighting load calculation

Space	Area	Target illuminance	No.of spaces	Lumens	Fixture type	No. of fixtures / space	Total fixtures	Wattage	No.of hours	Diversity factor	Energy consumed daily	Energy consumed anually
STUDENT ZONE												
Classrooms	60	300 lux	46	18000	Wipro High Lumen 22-Watt LED	4	184	22	5	0.9	18216	4426488
Canteen Jr.	100	150 lux	1	15000	Wipro garnet	8	8	20	5	0.9	720	174960
Canteen Sr.	50	150 lux	1	7500	Wipro garnet	4	4	20	5	0.9	360	87480
Labs	70	300 lux	5	21000	Wipro Garnet Wave Slim	11	55	20	5	0.9	4950	1202850
Art room	70	300 lux	1	21000	Wipro High Lumen 22-Watt LED	9	9	22	5	0.9	891	216513
Activity room	60	300 lux	3	18000	Wipro High Lumen 22-Watt LED	8	24	22	5	0.9	2376	577368
Library	300	300 lux	1	90000	Green LEDi	45	45	18	5	0.9	3645	885735
MPH	800	150 lux	1	120000	Green LEDi	60	60	18	5	0.9	4860	1180980
Printing room	10	150 lux	4	1500	Green LEDi (600lm)	3	12	18	5	0.9	972	236196
Kitchen	30	300 lux	1	9000	Wipro High Lumen 22-Watt LED	4	4	22	5	0.9	396	96228
Seminar hall	200	150 lux	1	30000	Green LEDi	15	15	18	5	0.9	1215	295245
R&D Block	150	500 lux	1	75000	Green LEDi	35	35	18	5	0.9	2835	688905
Toilets	52.5	100 lux	8	5250	Wipro garnet	3	24	20	5	0.9	2160	524880
LUNCH TIME												
Classrooms	60	300 lux	46	18000	Wipro high lumen 22-Watt LED	4	184	22	1	0.2	809.6	196732.8
Canteen Jr.	100	150 lux	1	15000	Wipro garnet	8	8	20	1	0.2	32	7776
Canteen Sr.	50	150 lux	1	7500	Wipro garnet	4	4	20	1	0.2	16	3888
Labs	70	300 lux	5	21000	Wipro Garnet Wave Slim	11	55	20	1	0.2	220	53460
Art room	70	300 lux	1	21000	Wipro High Lumen 22-Watt LED	9	9	22	1	0.2	39.6	9622.8
Activity room	60	300 lux	3	18000	Wipro High Lumen 22-Watt LED	8	24	22	1	0.2	105.6	25660.8
Library	300	300 lux	1	90000	Green LEDi	45	45	18	1	0.2	162	39366
MPH	800	150 lux	1	120000	Green LEDi	60	60	18	1	0.2	216	52488
Printing room	10	150 lux	4	1500	Green LEDi (600lm)	3	12	18	1	0.2	43.2	10497.6
Kitchen	30	300 lux	1	9000	Wipro High Lumen 22-Watt LED	4	4	22	1	0.2	17.6	4276.8
Seminar hall	200	150 lux	1	30000	Green LEDi	15	15	18	1	0.2	54	13122
R&D Block	150	500 lux	1	75000	Green LEDi	35	35	18	1	0.2	126	30618
Toilets	52.5	100 lux	8	5250	Wipro garnet	3	24	20	1	0.2	96	23328
OFFICE ZONE												
Staffrooms	30	300 lux	4	9000	Wipro garnet	5	20	20	8	0.9	2880	699840
Infirmary	20	300 lux	1	6000	Wipro Garnet Wave Slim	3	3	20	8	0.9	432	104976
Principal	20	300 lux	1	6000	Wipro garnet	3	3	20	8	0.9	432	104976
HOD room	15	300 lux	4	4500	Green LEDi	2	8	18	8	0.9	1036.8	251942.4
Admin	60	300 lux	1	18000	Wipro garnet	9	9	20	8	0.9	1296	314928
Staff commons	20	300 lux	1	6000	Wipro garnet	3	3	20	8	0.9	432	104976
Circulation area	2000	150 lux	1	300000	Green LEDi	150	150	18	8	0.9	19440	4723920
LUNCH TIME												
Staffrooms	30	300 lux	4	9000	Wipro garnet	5	20	20	1	0.3	120	29160
Infirmary	20	300 lux	1	6000	Wipro Garnet Wave Slim	3	3	20	1	0.3	18	4374
Principal	20	300 lux	1	6000	Wipro garnet	3	3	20	1	0.3	18	4374
HOD room	15	300 lux	4	4500	Green LEDi	2	8	18	1	0.3	43.2	10497.6
Admin	60	300 lux	1	18000	Wipro garnet	9	9	20	1	0.3	54	13122
Staff commons	20	300 lux	1	6000	Wipro garnet	3	3	20	1	0.3	18	4374
Circulation area	2000	150 lux	1	300000	Green LEDi	150	150	18	1	0.3	810	196830
TIME BEFORE SCHOOL												
Staffrooms	30	300 lux	4	9000	Wipro garnet	5	20	20	1	0.7	280	68040
Infirmary	20	300 lux	1	6000	Wipro Garnet Wave Slim	3	3	20	1	0.7	42	10206
Principal	20	300 lux	1	6000	Wipro garnet	3	3	20	1	0.7	42	10206
HOD room	15	300 lux	4	4500	Green LEDi	2	8	18	1	0.7	100.8	24494.4
Admin	60	300 lux	1	18000	Wipro garnet	9	9	20	1	0.7	126	30618
Staff commons	20	300 lux	1	6000	Wipro garnet	3	3	20	1	0.7	42	10206
Circulation area	2000	150 lux	1	300000	Green LEDi	150	150	18	1	0.7	1890	459270
												18245995.2
											Total lighting energy	**18245.9952 KWh**
												18245.9952

Appendix table 7: Lighting load calculations

Base case energy break-up

Equipment	HVAC	Lighting	Pumps	Ventilation
379710 Kwh/yr	16600 Kwh/yr	95180 Kwh/yr	15000 Kwh/yr	16000 Kwh/yr

Heat pump load calculation

For 30 Kw nominal capacity , energy input = 6.83 Kw

For 1000 litres of water , i.e , 1000 kg , heat required to rise its temperature by 30 degree centigrade is

Q= m . Cp . T

= 1000 . 4.18 X 30

= 125400 KJ

Amount of time required for heating = Heat required / capacity

= 125400 KJ / 30 KW

= 4180 seconds

= 1.16 hours

Work input = 6.83 x 1.16 = 7.922 = 8KWh

Thus we need to supply 8 KWh per day to raise the temperature of 1000l of water by 30 degrees centigrade.

Lighting equipment optimisation

Fixture type	Lumens	Wattage	Luminous efficacy
Wipro High Lumen 22-Watt LED	4800	22	218 lm/watt
Wipro garnet	1900	20	95 lm/watt
Wipro Garnet Wave Slim	2058	20	102.9 lm/watt
Green LEDi	2000	18	111.1 lm/watt

As per GRIHA guidelines , the lighting equipment chosen have luminous efficacy of at least 75 lumens/ watt

Wipro high lumen LED

Wipro Garnet

Wipro Garnet wave slim

Green LEDi

Equipment optimisation

Equipment	Model chosen	Wattage	Standard equipment wattage
Smart boards	MAXHUB Smart board	220	340
Laptops	DELL TCO certified(education)	150	300
Computers	DELL inspiron Desktop TCO certified	45	500
Printers	Canon PIXMA G5020	35	50
Projectors	BENQ V7050i	500	800
Microwave	Panasonic Genius Sensor	950	1000
Induction	HP4920 Induction cook top	1500	3000
Coffee machine	Russel hobbs coffee maker	1000	1300
Ceiling fans	Crompton energion HS (BEE 5 star)	34	75
CC Cameras	CP Plus CCTV Camera	5	40
Refrigerator	LG GBB92MCBAP (A grade acc. to EU)	28.4	100
Water purifier	HUL Pureit Eco Water Saver	36	40

Equipment for the project are chosen from multiple options available , based on their efficiency , energy consumption & cost.

Appendix table 8: Equipment optimization

DOAS Calculations

DOAS system is sized seperately for MPH and School zone seperately.

Dew point temperature for DOAS system – 25.8 degrees celcius

CFM for MPH – 6640

CFM for School zone – 3600

Renewable energy calculation

Solar panels

Solar panel energy generation is calculated for various tilt angles and the most efficient tilt angle of 28 degrees is chosen.
LG Solar panels , LG440N2T-E6 are chosen for the project , amongst all the available options , due to its 19.8% highest efficiency .
Warranty of the solar panels is 25 years.
It Absorbs up to 30% more light than conventional models.

Solar panels

Month	No.of working days	Energy consumptior	Energy generation
January	20 days	18290.14561	20015
Febraury	23 days	21033.66745	18981
March	24 days	21948.17473	22698
April	24 days	21948.17473	18611
May	24 days	21948.17473	17362
June	4 days	3658.029122	16050
July	21 days	19204.65289	16401
August	23 days	21033.66745	16623
September	24 days	21948.17473	17178
October	15 days	13717.60921	20247
November	22 days	20119.16017	20176
December	19 days	17375.63833	18147
		Total	222489 KWh/yr

Appendix table 9: Energy generation through solar panels

Impulse turbine

Month	Harvested rainwater in cubic metres	Net power generated
January	43	18 KWh
Febraury	97	41 KWh
March	232	97 KWh
April	128	53 KWh
May	183	76 KWh
June	1818	760 KWh
July	2185	913 KWh
August	1914	800 KWh
September	1342	561 KWh
October	491	205 KWh
November	58	24 KWh
December	23	10 KWh
	Total = 8514	3558 KWh

Appendix table 10: Power generated through impulse turbine

Assam Net metering guidelines

The following information and guidelines are sourced from AERC (GRID INTERACTIVE SOLAR PV SYSTEMS) , REGULATIONS ,2019.
Our solar PV system is designed with a grid tie inverter and an exim meter (net meter) , so that the net energy after consumption is given back to the grid and is drawn from the grid in case of shortfall.
Solar PV is owned by the Gyandeep foundation.
Solar panel generation capacity - 222500 KWh = 222.5 KWp (Our installation capacity falls under the eligibility (1KWp-1000KWp) to participate in grid interactive solar PV systems of Assam).

A grid tie inverter is used as a protection against islanding and

Grid tie inverter capacity - 30 KW

HVAC load optimisation for design case

SOLAR GAIN - GLASS						
Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	SHGC	BTU / Hour
Glass	N	0	39	1.3	0.47	0
Glass	NE		11	1.3	0.47	0
Glass	E	0	11	1.3	0.47	0
Glass	SE		11	1.3	0.47	0
Glass	S	107	11	1.3	0.47	693
Glass	SW		66	1.3	0.47	0
Glass	W	0	158	1.3	0.47	0
Glass	NW		158	1.3	0.47	0
Skylight			107	1.3	0.47	0
SOLAR & TRANSMISSION GAIN - WALL & ROOF						
Item	Direction	Area (ft^2)	ΔT (°F)	Correction fator	U-value	BTU / Hour
Wall	N	2600	4	3	0.28	5096
Wall	NE		10	3	0.28	0
Wall	E	367	18	3	0.28	2156
Wall	SE		18	3	0.28	0
Wall	S	2493	16	3	0.28	13263
Wall	SW		14	3	0.28	0
Wall	W	367	12	3	0.28	1540
Wall	NW		6	3	0.28	0
Roof		13024	32	3	0.28	127635
TRANSMISSION GAIN EXCEPT WALLS & ROOF						
Item		Area (ft^2)	ΔT (°F)		U-value	BTU / Hour
All Glass		107	7.4		0.497	394
Door		21	7.4		1.13	176
Partition			2.4			0
Ceiling			2.4			0
Floor			2.4			0
INTERNAL SENSIBLE HEAT						
	Quantity	Unit rates				BTU / Hour
People	1200	220				264000
Equip (W)	3000	3.41			1	10230
Lights (W)	1000	3.41			1	3410
Supply air fan gain	5%					21430
INTERNAL LATENT HEAT						
	Quantity	Unit rates				BTU / Hour
People	200	205				41000
OUT SIDE AIR HEAT						
	Flow rate (CFM)	ΔT(°F) & Δg/lb	Convesion factor			BTU / Hour
Sensible	2117	7.4	1.08			16919
Latent	2117	5.0	0.68			7198
Total Room Sensible heat						466940
Total Room Latent heat						48198
Grand total heat, BTU/hr						515137
AIR CONDITIONING TONNAGE						42.93

Appendix table 11 : HVAC load optimisation

HVAC load is optimized through various factors such as choosing the materials for the wall and roof with a low u value, the orientation of the building, choosing efficient equipment and also using a double-glazed window which has a solar heat gain coefficient of 0.47. So, the heat gain through various means is reduced.

The load is further optimised by creating set points through which HVAC is operated.

12.8 DETAILED CALCULATIONS OF ENERGY REQUIREMENTS DURING HAZARDS

RESILIENCE TIME - Flood					
APPLIANCE	**Quantity**	**Wattage (W)**	**No.of hours / day**	**Diversity fa**	**Energy consumed daily (W)**
Induction	2	1500	24	0.95	68400
6A Sockets	50	100	24	0.95	114000
PHE	1	15	24	0.95	342
CC Cameras	78	5	24	0.95	8892
Refrigerator	4	28.4	24	0.95	2590.08
Fire alarm	85	45	24	0.95	87210
Water purifier	8	36	24	0.95	6566.4
Jockey pumps	1	365.52	24	0.95	8333.856
Hydrant pumps	1	365.52	24	0.95	8333.856
STP pumps	1	365.52	24	0.95	8333.856
Exhaust fans	14	16	24	0.95	5107.2
INTERIOR LIGHTING					90335.3
IOT					720
				Total energ	409164.548
					409.164548
				For 4days	1636.658192
					1600 KWh

Appendix table 12 : Energy requirements during flood

RESILIENCE TIME - Earthquake					
APPLIANCE	**Quantity**	**Wattage (W)**	**No.of hours / da**	**Diversity factor**	**Energy consumed daily (W)**
Induction	2	1500	24	0.95	68400
Ceiling fans	195	28	24	0.95	124488
CC Cameras	78	5	24	0.95	8892
Fire alarm	85	45	24	0.95	87210
Jockey pumps	1	365.52	24	0.95	8333.856
Hydrant pumps	1	365.52	24	0.95	8333.856
STP pumps	1	365.52	24	0.95	8333.856
Exhaust fans	14	16	24	0.95	5107.2
IOT					720
6A Sockets	50	100	24	0.95	114000
				Total energy	433818.768
					433.818768
				For 3 days	1301.456304
					1600 kwh

Appendix table 13: Energy requirements during earthquake

RESILIENCE TIME - THUNDER STORM					
APPLIANCE	**Quantity**	**Wattage (W)**	**No.of hours / da**	**Diversity factor**	**Energy consumed daily (W)**
Ceiling fans	195	28	24	0.95	124488
CC Cameras	78	5	24	0.95	8892
Fire alarm	85	45	24	0.95	87210
Jockey pumps	1	365.52	24	0.95	8333.856
Hydrant pumps	1	365.52	24	0.95	8333.856
STP pumps	1	365.52	24	0.95	8333.856
6A Sockets	50	100	24	0.95	114000
IOT					720
				Total energy	360311.568
	-				360.311568
				For 4 days	1441.246272
					1450 KWh

Appendix table 13: Energy requirements during thunderstorms

RESILIENCE TIME - FIRE					
APPLIANCE	**Quantity**	**Wattage (W)**	**No.of hours / day**	**Diversity fa**	**Energy consumed daily (W)**
Ceiling fans	195	28	24	0.95	124488
CC Cameras	78	5	24	0.95	8892
Fire alarm	85	45	24	0.95	87210
Jockey pumps	1	365.52	24	0.95	8333.856
Hydrant pumps	1	365.52	24	0.95	8333.856
STP pumps	1	365.52	24	0.95	8333.856
Exhaust fans	14	16	24	0.95	5107.2
IOT					720
6A Sockets	50	100	24	0.95	114000
				Total energ	365418.768
					365.418768
				For 3 days	1096.256304
					1100 KWh

Appendix table 14 : Energy requirements during fire

12.9 WATER CALCULATIONS

BASE CASE	LPF		Minutes	No. of uses	Consumption per day in lts	GREY WATER	BLACK WATER
Water closets (Full flusing)							
wc solid	6	1 flush		1	6		100%
wc liquid	3	1 flush	1	2	6		100%
Urinals (male)	2.2	1 flush	1	3	6.6		100%
	LPM						
Basin mixer	8	15 seconds	0.25	3	6	100%	
Health faucets	8	15 seconds	0.25	2	4		100%
Shower head	15	8 minutes	8	0.1	12	100%	
Kitchen faucet	6	15 seconds	0.25	1.25	1.875		100%
Cooking	5			0.5	2.5		100%
Drinking	2			half day	2		100%
Washing	6			0.2	1.2	100%	
cleaning	3				3	100%	
TOTAL					45.175		

Appendix Table 15: Base case breakup in normal condition

PROPOSED CASE	LPF		Minutes	No. of uses	Consumption per day in lts	GREY WATER	BLACK WATER
Water closets (compost toilet)							
wc solid	0.28	1 flush		1	0.28		100%
wc liquid	0.28	1 flush	1	3	0.84		100%
Urinals (male)	0	1 flush	1	3	0		100%
	LPM						
Sensor faucet	1.8	15 seconds	0.25	3	1.35	100%	
Health faucets	4	15 seconds	0.25	2	2		100%
Shower head	7.58	8 minutes	8	0.1	6.064	100%	
Kitchen faucet (sensor)	3	15 seconds	0.25	1.25	0.9375		100%
cooking	5			0.32	1.6		100%
drinking	2				2		100%
cleaning	1.5			243	1.5	100%	
Washing	2			0.1	0.2	100%	
Total					16.7715		

Appendix table 16 : Design case breakup in normal condition

Base case		occupants activity	Proposed case	
Quantity in lts for 2000 people	quantity in l/person/day		quantity in l/person/day	Quantity in lts for 2000 people
3000	6	handwash	1.35	675
1000	2	drinking	2	1000
2150	4.3	kitchen	2.63	1315
6000	12	shower	6	3000
1500	3	cleaning	1.5	750
2600	5.2	washing	2.4	1200
3300	6.6	urinal flushing	0	0
3000	6	wc flushing	0.84	420
22550	45.1		16.72	8360

Appendix table 17 : Occupants activity in normal conditions

Number of Occupants =2000	BASE CASE	DESIGN CASE
Per Capita Daily Consumption(L)	45L	16.264L
Total Daily Consumption(L)	90,000L	32,528L
Total Yearly Consumption(L)	2,18,70,000L	79,04,304L

Month	Days in month	working days in a month	Rainfall (mm)	Effective rain (mm)	Harvested water (l)	Muncipality water supply (l)	Primary demand (l)	total storage (l)	Capacity of rain water tank(total storage - fire tank, ugt, oht storage)
July	31	21	570	565	2257175	0	635880	1621295	1455295
August	31	23	500	495	1977525	0	696440	2902380	2736380
September	30	24	352	347	1386265	0	726720	3561925	3395925
October	31	15	132	127	507365	0	454200	3615090	3449090
November	30	22	20	15	59925	0	666160	3008855	2842855
December	31	19	11	6	23970	0	575320	2457505	2291505
January	31	20	16	11	43945	0	605600	1895850	1729850
February	28	23	30	25	99875	0	696440	1299285	1133285
March	31	24	65	60	239700	0	726720	812265	646265
April	30	24	38	33	131835	0	726720	217380	51380
May	31	24	285	280	1118600	0	726720	609260	443260
June	30	4	475	470	1877650	0	121120	2365790	2199790
Total	365	243	2494	2434	9723830	0	7358040		
Total in Kl					9720		7360		

Appendix table 18: Harvested and demand of fresh water

BASE CASE	LPF		Minutes	No. of uses	Consumption per day	GREY WATER	BLACK WATER
Water closets (Full flusing)							
wc solid	6	2 flush		2	12		100%
wc liquid	3	1 flush	1	4	12		100%
Urinals (male)	3.8	1 flush	1	3	11.4		100%
	LPM						
Basin mixer	6	15 seconds	0.25	12	18	100%	
Health faucets	6	15 seconds	0.25	3	4.5		100%
Shower head	10	8 minutes	8	0.25	20	100%	
Kitchen faucet	10	15 seconds	0.25	1.25	3.125		100%
Cooking	1.9			1	1.9		100%
Drinking	5			1	5		100%
Washing	9.5			1	9.5	100%	
cleaning	10				10	100%	
TOTAL					95.4		

Appendix table 19: Base case breakup in disaster condition

PROPOSED CASE	LPF		Minutes	No. of uses	Consumption per day	GREY WATER	BLACK WATER
Water closets (compost toilet)							
wc solid	0.28	1 flush		2	0.56		100%
wc liquid	0.28	1 flush	1	4	1.12		100%
Urinals (male)	0	1 flush	1	3	0		100%
	LPM						
Sensor faucet	1.8	15 seconds	0.25	12	5.4	100%	
Health faucets	4	15 seconds	0.25	3	3		100%
Shower head	7.58	8 minutes	8	0.25	15.16	100%	
Kitchen faucet (sens	4	15 seconds	0.25	1.25	1.25		100%
cooking	3.75			1	3.75		100%
drinking	5			1	5		100%
cleaning	5			243	5	100%	
Washing	11			1	11	100%	
Total					50.68		

Appendix table 20: Design case breakup in disaster condition

Base case		occupants activity	Proposed case	
Quantity in lts for 500 people	quantity in l/person		quantity in l/person	Quantity in lts for 500 people
9000	18	handwash	5.4	2700
2500	5	drinking	5	2500
2500	5	kitchen	5	2500
10000	20	shower	15	7500
5000	10	cleaning	5	2500
7000	14	washing	14	7000
5700	11.4	urinal flushing	0	0
6000	12	wc flushing	1.12	560
47700	95.4		50.52	25260

Appendix table 21: Occupants activity in disaster condition

TANKS	SIZE (Litres)	water to be stored in liters	Volume(m3)	Dimensions of tank
	UNDERGROUND TANK			
1	Fresh water (Treated rain water)	50000	50	2 x 2.4 m dia x 0.5m length
2	Treated Water (Recycled greywater +Surface runoff rainwater)	37000	37	5x4x2
3	Fire water tank	100000	100	5x6.2x3
	OVERHEAD TANK			
1	Fresh water (Treated rain water)	16264	16.264	3x 3.7x1.5
2	Treated Water (Recycled greywater +Surface runoff rainwater)	2000	2	2x1x1
	RAIN WATER TANK	3400000	3400	40x29x3

Appendix table 22: Tank sizing

12.10 EXTRA COST OF EEFFICIENT EQUIPMENT USED IN THE DESIGN CASE

Sno	Item	Base Case Cost (INR Million)	Design Case Cost (INR Million)	Cost Difference
1	Movable Bamboo Parition Walls 110 mm thick		0.1	0.1
2	Rotatable Acoustic partitions		0.2	0.2
3	Light Shelves for Windows		0.1	0.1
4	Structural Glazing - North Light Roof		5.6	5.6
5	Shading Device Bamboo - North		0.4	0.4
6	Shading Device Bamboo - South with glazing		0.8	0.8
7	Shading Device Bamboo - East with glazing		0.3	0.3
8	Shading Device Bamboo - West		0.2	0.2
9	Sandwich Panels for Roofing		2.9	2.9
10	Bamboo Truss System - North Light		1.6	1.6
11	Solar PV System	2	6.1	4.1
12	Miscellaneous Items		1.2	1.2
13	Heat Pump		0.3	0.3
14	ECO STP		1.8	1.8
15	Underground Water Tank PVC		0.3	0.3
16	Overhead Water Tank PVC		0	0
17	Biogas Plant		0.4	0.4
18	Impulse Turbine		0.2	0.2
19	Rain Water Harvesting	1.7	3.4	1.7
20	Rainwater filters		0.4	0.4
21	CCTV System	0.6	1.6	1
22	Building Management System	1.2	3.2	2
23	Waterleak detection system	0.1	0.1	0
24	Water Level Detection Sensors		0	0
25	LAN System	4.2	5.1	0.9
26	Conference System		7.5	7.5
27	Street lighting with LED		0.8	0.8
28	Illuminated Signs		0.1	0.1
29	Earthquake Desks		5.5	5.5
30	Indoor Plants		0	0
31	Bamboo Plantation		0	0
	Total Cost			**40.4**

	Amount Spent (INR Million) - Base Case				Amount Spent (INR Million) - Design Case				Amount Saved (INR Million) - Design Case			
	Year 1	Year 2	Year 35		Year 1	Year 2	Year 35		Year 1	Year 2	Year 35	**Total Saved - 35 yrs**
Maintenance & Repair Costs	12.28	12.28	12.28		9.21	9.21	9.21		3.07	3.07	3.07	**107.45**
Elecrical Supply Costs	3.6	3.6	3.6		0	0	0		3.6	3.6	3.6	**126**
Water Supply Costs	2.9	2.9	2.9		0	0	0		2.9	2.9	2.9	**101.5**

Total Amount Saved (35 years)	334.95
Total Amount Invested in Design Case (after repayment of loans)	332.2215

Appendix table 23: Extra cost of energy, water, carbon efficient equipment used in Design Case + ROI on entire building Investment

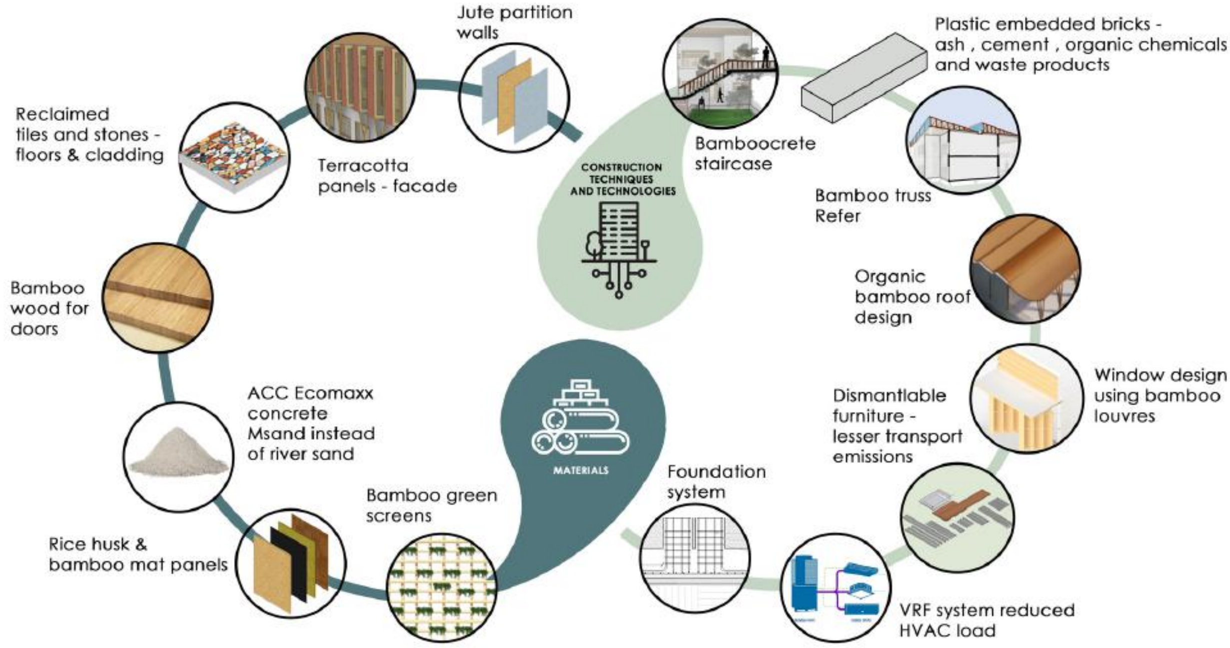
12.11 SUMMARY OF COST ESTIMATE

Project Summary								
S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount in Million INR	%	Amount (INR per sqm)	Amount in Million INR	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased by the Project Partner	2.50	0.8%	310	2.50	0.8%	310
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	115.76	37.7%	14,341	73.11	23.8%	9,058
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	45.92	14.9%	5,688	49.59	16.1%	6,144
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	82.88	27.0%	10,268	74.35	24.2%	9,211
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	0.02	0.0%	2	4.61	1.5%	571
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	13.59	4.4%	1,683	19.24	6.3%	2,383
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	12.91	5.0%	1,599	11.04	5.0%	1,368
	TOTAL HARD COST		**273.57**	**89.8%**	**33,891**	**234.44**	**77.7%**	**29,044**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	15.00	4.9%	1,858	15.00	4.9%	1,858
9	Consultants	Consultant fees on a typical Project	15.00	4.9%	1,858	15.00	4.9%	1,858
10	Interest During Construction	Interest paid on loans related to the project during construction	3.75	1.2%	464	2.21	0.7%	273
	TOTAL SOFT COST		**33.75**	**11.0%**	**4,181**	**32.21**	**10.5%**	**3,990**
	TOTAL PROJECT COST		**307.32**	**100.0%**	**38,072**	**266.65**	**86.8%**	**33,034**

Appendix table 24: Summary of cost estimate

Detailed costing sheet attached separately.

12.12 SUMMARY OF EMBODIED CARBON CALCULATIONS



Appendix figure 8 : Construction techniques and materials used

WALL

Material	Unit	Material manufacturing emissions			Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
		Quantity	Emissions Factor	Material Emissions (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg -CO_2 e)
AAC	kg	10713.6	0.5	5357	Mini truck	101	8	832	42	118	Mini truck	60	8	494	25	70
Cement (ordinary Portland cement, OPC)	kg	980.035	0.91	892	<select vehicle>	0	0	0	0	0	Mini truck	6	1	5	0	1
M-sand	kg	2371.992	0.009	21	<select vehicle>	0	0	0	0	0	Mini truck	12	2	22	1	3
Paint	l	2.5	0.659	2	<select vehicle>	0	0	0	0	0	Bike	9	0	0	0	0
			Total material emissions per functional unit (kg -CO_2 e)	63					Total Transport 1 emissions per functional unit (kg -CO_2 e)	1					Total Transport 2 emissions per functional unit (kg -CO_2 e)	1

Appendix table 25 : System type : wall, System name : AAC wall, Area : 100sq.m – Basecase

Material	Unit	Material manufacturing emissions			Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
		Quantity	Emissions Factor	Material Emissions (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg -CO_2 e)
Zerund bricks	kg	11544	-0.15	-1732	<select vehicle>	0	0	0	0	0	HGV Lorry/ Truck	112	0	32	5	15
Cement/lime render for exte	kg	906.57	0.27	245	<select vehicle>	0	0	0	0	0	Mini truck	6	1	4	0	1
Bamboo poles	kg	770	-0.18	-139	Mini truck	25	1	15	1	2	Mini truck	12	1	7	0	1
Bamboo mat board	kg	1047	-0.13	-136	<select vehicle>	0	0	0	0	0	Mini truck	112	1	90	5	13
			Total material emissions per functional unit (kg -CO_2 e)	-18					Total Transport 1 emissions per functional unit (kg -CO_2 e)	0					Total Transport 2 emissions per functional unit (kg -CO_2 e)	0

Appendix table 26 : System type : wall, System name : Zerund Blocks wall, Area : 100sq.m – Designcase

ROOF

Material	Unit	Material manufacturing emissions			Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
		Quantity	Emissions Factor	Material Emissions (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg -CO_2 e)
Cement (ordinary Portland cement, OPC)	kg	5400	0.91	4914	<select vehicle>	0	0	0	0	0	Mini truck	6	4	25	1	4
M-sand	kg	6937	0.009	62	<select vehicle>	0	0	0	0	0	Mini truck	12	5	64	3	9
Aggregate (mixed gravel/crushed stone)	cu. m	7.5	0.009	0	<select vehicle>	0	0	0	0	0	Mini truck	30	0	0	0	0
Bitumen WPC	Kg	450	0.46	207	Car	101	2	227	11	32	Car	8	2	18	1	3
Cement floor screed (concrete screed)	kg	8000	0.18	1440	<select vehicle>	0	0	0	0	0	Mini truck	6	6	37	2	5
			Total material emissions per functional unit (kg -CO_2 e)	66					Total Transport 1 emissions per functional unit (kg -CO_2 e)	0					Total Transport 2 emissions per functional unit (kg -CO_2 e)	0

Appendix table 27 : System type : Roof, System name : RCC flat slab, Area : 100sq.m – Basecase

Material	Unit	Material manufacturing emissions			Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
		Quantity	Emissions Factor	Material Emissions (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg -CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg -CO_2 e)
Bamboo corrugated roof she	kg	912	-0.27	-246	<select vehicle>	0	0	0	0	0	Mini truck	148	1	104	5	15
Glass wool (fibreglass)	kg	1280	1.35	1728	<select vehicle>	0	0	0	0	0	Mini truck	51	1	50	3	7
Bamboo poles	kg	700	-0.18	-126	Mini truck	30	1	16	1	2	Mini truck	12	1	6	0	1
			Total material emissions per functional unit (kg -CO_2 e)	14					Total Transport 1 emissions per functional unit (kg -CO_2 e)	0					Total Transport 2 emissions per functional unit (kg -CO_2 e)	0

Appendix table 28 : System type : Roof, System name : Northlight truss, Area : 100sq.m – Designcase

FLOOR

Material	Unit	Quantity	Emissions Factor	Material Emissions (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg-CO_2 e)
Cement mortar	kg	10810	0.14	1513	<select vehicle>	0	0	0	0	0	Mini truck	6	8	50	2	7
Stone floor tile	kg	1945	0.056	109	Mini truck	119	1	178	9	25	Mini truck	6	1	9	0	1
Ready mix concrete with ordi	kg	32000	0.11	3520	<select vehicle>	0	0	0	0	0	Mini truck	35	25	862	43	122
Steel reinforcement (steel re	kg	1200	2.6	3120	<select vehicle>	0	0	0	0	0	Mini truck	11	1	10	1	1
			Total material emissions per functional unit (kg-CO_2 e)	83					Total Transport 1 emissions per functional unit (kg-CO_2 e)	0					Total Transport 2 emissions per functional unit (kg-CO_2 e)	1

Appendix table 29 : System type : Floor, System name : Kota stone, Area : 100sq.m – Basecase

Material manufacturing emissions					Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
Material	Unit	Quantity	Emissions Factor	Material Emissions (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg-CO_2 e)
Acc ecomaxx	kg	23000	0.06	1380	<select vehicle>	0	0	0	0	0	Mini truck	6	18	106	5	15
Steel reinforcement (steel re	kg	800	2.6	2080	<select vehicle>	0	0	0	0	0	Mini truck	12	1	7	0	1
Clay pots	kg	280	0.24	67	<select vehicle>	0	0	0	0	0	Mini truck	30	0	6	0	1
			Total material emissions per functional unit (kg-CO_2 e)	35					Total Transport 1 emissions per functional unit (kg-CO_2 e)	0					Total Transport 2 emissions per functional unit (kg-CO_2 e)	0

Appendix table 30 : System type : Floor, System name : Filler slab, Area : 100sq.m – Designcase

FENESTRATION

Material manufacturing emissions					Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
Material	Unit	Quantity	Emissions Factor	Material Emissions (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg-CO_2 e)
Hollock timber	kg	1500	1.8	2700	<select vehicle>	0	0	0	0	0	Mini truck	30	1	35	2	5
Float glass	kg	100	1.2	120	<select vehicle>	0	0	0	0	0	Mini truck	12	0	1	0	0
			Total material emissions per functional unit (kg-CO_2 e)	0					Total Transport 1 emissions per functional unit (kg-CO_2 e)	0					Total Transport 2 emissions per functional unit (kg-CO_2 e)	0

Appendix table 31 : System type : Fenestration, System name : Assam Hollock timber, Area : 100sq.m – Basecase

Material manufacturing emissions					Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
Material	Unit	Quantity	Emissions Factor	Material Emissions (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg-CO_2 e)
Bamboo ply	kg	1800	-0.17	-306	<select vehicle>	0	0	0	0	0	Mini truck	67	1	93	5	13
Float glass	kg	150	1.2	180	<select vehicle>	0	0	0	0	0	Mini truck	12	0	1	0	0
			Total material emissions per functional unit (kg-CO_2 e)	-1					Total Transport 1 emissions per functional unit (kg-CO_2 e)	0					Total Transport 2 emissions per functional unit (kg-CO_2 e)	0

Appendix table 32 : System type : Fenestration, System name : Bambooply, Area : 100sq.m – Designcase

STRUCTURE

		Material manufacturing emissions			Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
Material	Unit	Quantity	Emissions Factor	Material Emissions (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg-CO_2 e)
Steel reinforcement (steel re	kg	459	2.6	1193	<select vehicle>	0	0	0	0	0	Mini truck	11	0	4	0	1
Cement (ordinary Portland ce	kg	6900	0.91	6279	<select vehicle>	0	0	0	0	0	Mini truck	6	5	32	2	5
M-sand	kg	5400	0.009	49	<select vehicle>	0	0	0	0	0	Mini truck	12	4	50	2	7
Aggregate (mixed gravel/crus	cu. m	7.5	0.009	0	<select vehicle>	0	0	0	0	0	Mini truck	30	0	0	0	0
			Total material emissions per functional unit (kg-CO_2 e)	75					Total Transport 1 emissions per functional unit (kg-CO_2 e)	0					Total Transport 2 emissions per functional unit (kg-CO_2 e)	0

Appendix table 33 : System type : Structure, System name : RCC, Area : 100sq.m – Basecase

		Material manufacturing emissions			Transport 1 | Manufacturer --> Supplier						Transport 2 | Supplier --> Site					
Material	Unit	Quantity	Emissions Factor	Material Emissions (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Factory to Retail shop (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 1 (kg-CO_2 e)	Type of Vehicle used	(1) Distance from Retail shop to Site (km)	(2) No. of trips	(3) Total distance = (1)* (2) (km)	(4) Total Fuel Consumed = (3)/Mileage (litres)	Transport Emissions 2 (kg-CO_2 e)
Steel reinforcement (steel re	kg	459	2.6	1193	<select vehicle>	0	0	0	0	0	Mini truck	12	0	4	0	1
Acc ecomaxx	kg	36098	0.06	2166	<select vehicle>	0	0	0	0	0	Mini truck	158	28	4387	219	623
			Total material emissions per functional unit (kg-CO_2 e)	34					Total Transport 1 emissions per functional unit (kg-CO_2 e)	0					Total Transport 2 emissions per functional unit (kg-CO_2 e)	6

Appendix table 34 : System type : Structure, System name : ACC Ecomaxx, Area : 100sq.m – Designcase

12.13 BUILDING OPERATION NARRATIVE

OPERATIONS-DO's and DON'Ts

SOLAR PANELS

DO's

- The panels are cleaned at least once every fifteen days.
- Servicing of HT side equipment on an annual basis
- Diagnosis and tests pertaining to low solar power production
- Use water and a soft sponge or cloth for cleaning.
- Iso-propyl alcohol may be used to remove oil or grease stains.

DON'Ts

- Use detergent or any abrasive material for panel cleaning.
- Spray water on the panel if the panel glass is cracked or the back side is perforated
- Climb on your roof unless trained, experienced and wearing proper personal protective and fall-protection equipment
- Avoid using a high-pressure washer.
- Do not use any metallic objects

RED OXIDE FLOORING

DO's

- Test all products before applying
- Use a soft-bristled broom or a dust mop to pick up debris.
- Use soft materials for wiping the dirt or stains off the surface.
- Scrub a newly coated oxide floor once a week, but do not use abrasive materials
- Give time for a cleaning material to react on one spot before going through the cleaning.

DON'Ts

- Use bleach for cleaning
- Put wax or sealers
- Mix various types of cleaners
- Use cleaners with crystallization salt and harmful alkali compound
- Mop with cleaners that are acid/soap based, like a vinegar solution,

LANDSCAPE

DO's

- Check For Tree Diseases And Pests
- Carry Out Regular Pruning
- Water the plants on regular basis
- Collect dry leaves for composting

DON'Ts

- Water Trees too much
- Allow students to swing on the trees
- Over-fertilize.(It could cause root damage)

FIRE SAFETY

DO's

- Faulty electrical appliances should be repaired/ replaced immediately.
- Evacuation drills should be conducted at regular intervals
- Fire safety equipment should be maintain high standards and checked at regular intervals
- Always switch off high-wattage electrical appliances if not used for a long time
- Emergency light's working should be checked and maintained at regular intervals
- Proper maintenance of Fire exit door

DON'Ts

- Apply any paint on Fire Detectors/ Sprinkler Heads
- Extinguish the fire yourself
- Have objects / obstacles in the fire exit passage
- Check battery life for power back up during emergency

STP

DO's

- Electrical supply to the treatment plant must be maintained constantly
- Service engineer to carry out regular service schedule
- Bleach can be used sparingly

DON'Ts

- Flush rubber products or other non-biodegradable products down the toilet
- Allow rainwater, groundwater or large volumes of water (such as those from a swimming pool) into the plant
- Medicines and any other chemicals should not be disposed of down the drains either

RAIN WATER HARVESTING

DO's

- Clean your roof every two weeks
- Make sure you have a lid that fits tightly
- Nesting of birds on the roof should be prevented
- Clean your tank once every six months
- Provide gratings at every downpipe on terrace

DON'Ts

- Use hazardous substances, chemicals, or paints on your roof
- Leave the tank uncovered during any dry periods because dust will find a way in
- Drink collected rainwater directly
- Leaving cracks on pipe untreated / not repaired
- Using same water filter for more 3 months

ELECTRICAL SAFETY

DO's

- Obey warnings to stay away from electrical circuits and locked-out equipment.
- Report and electrical problems immediately
- Use insulating maps on damp surfaces.
- Locate electrical wires before drilling a hole in the wall

DON'Ts

- Store materials temporarily or permanently within 3 feet of any electrical panel or electrical equipment.
- Plug equipment into defective receptacles.
- Overload motors, circuits, or outlets
- Touch anything electric with wet hands

BAMBOO PRODUCTS (windows, doors, bench and shading devices)

DO's

- Clean bamboo on a regular basis.
- Cracks to be repaired immediately.
- Cure bamboo for termites
- Replacing bamboo if found to be weak.

DON'Ts

- Applying high impact load on products.
- Applying chemicals or other harmful products on bamboo without prior knowledge.

12.14 EARTHQUAKE SIMULATION

ALLOWABLE BEARING CAPACITY FROM SHEAR CRITERIA AND SETTLEMENT CRITERIA

Depth (m)	Footing size (m)	S.B.C. (Shear criteria) (kN/m²)	S.B.P. (Settlement criteria) (kN/m²)	Allowable Bearing Capacity (kN/m²)
1.5	1.5 × 1.5	98.68	148.03	98.68
	1.8 × 1.8	96.36	126.02	96.36
	2.0 × 2.0	95.21	115.99	95.21
2.0	1.5 × 1.5	105.02	172.73	105.02
	1.8 × 1.8	102.05	145.10	102.05
	2.0 × 2.0	100.56	132.54	100.56
2.5	1.5 × 1.5	[illegible]	[illegible]	[illegible]
	1.8 × 1.8	107.45	164.21	107.45
	2.0 × 2.0	105.66	149.13	105.66
3.0	1.5 × 1.5	116.63	222.08	116.63
	1.8 × 1.8	112.54	183.28	112.54
	2.0 × 2.0	110.49	165.68	110.49
3.5	1.5 × 1.5	121.91	246.72	121.91
	1.8 × 1.8	117.34	202.40	117.34
	2.0 × 2.0	115.05	182.26	115.05

Appendix table 35 : Table showing allowable bearing capacity.

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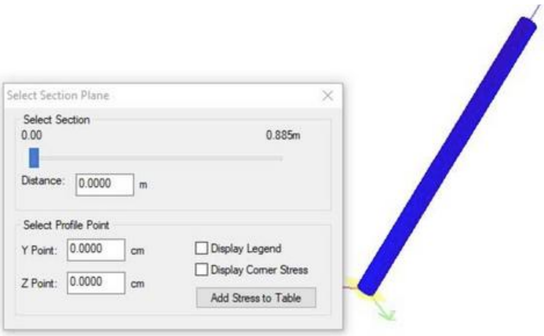
Reasons for choosing Isolated footing over Pile footing which the client had proposed:

- Our building design is G+1 floor as compared to G+2 design by the client(More load acting on footing)
- The span of the structure is 6m*5m compared to 7.5m*7.5m for the client's design.
- The pile foundation was not an efficient choice of footing system for the amount of load acting.
- Isolated footing is economical compared to the pile and required less material
- Draining out water from footing is harder in pile compared to the isolated footing.

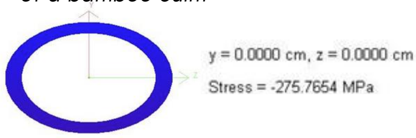
EARTHQUAKE SIMULATION

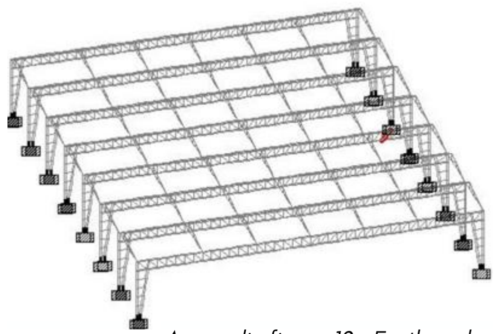
FOR BAMBOO PORTAL FRAMES USED IN THE MPH

STAAD.pro



Appendix figure 9: Tensile stress of a bamboo culm





Appendix figure 10 : Earthquake Structure modelling in Rhino

GC Str - Beam Stress

Beam	L/C	Section	Axial MPa
1272	6	0.333	-275.747
1272	6	0.417	-275.748
1272	6	0.500	-275.749
1272	6	0.583	-275.750
1272	6	0.667	-275.750
1272	6	0.750	-275.751
1272	6	0.833	-275.752
1272	6	0.917	-275.753
1272	6	1.000	-275.754
1658	6	0.000	-275.765
1658	6	0.083	-275.766
1658	6	0.167	-275.767
1658	6	0.250	-275.768
1658	6	0.333	-275.769
1658	6	0.417	-275.769
1658	6	0.500	-275.770
1658	6	0.583	-275.771
1658	6	0.667	-275.772
1658	6	0.750	-275.772
1658	6	0.833	-275.773
1658	6	0.917	-275.774
1658	6	1.000	-275.775

Appendix table 36 : Beam Stress

Tensile strength of bamboo for various culm diameters and wall thicknesses

Culm diameter (mm)	Wall thickness (mm)	Tensile strength (MPa)
80–90 *Class 1*	6–7	281
	7–8	295
	8–9	285
90–100 *Class 2*	6–7	260
	7–8	298
	8–9	292
	9–10	280
	10–11	294
100–110 *Class 3*	6–7	288
	7–8	290
	8–9	285
	9–10	287
	10–11	301
110–120 *Class 4*	6–7	324
	7–8	320
	9–10	326
120–130 *Class 5*	8–9	340
	9–10	318
	10–11	303
	11–12	268
30–140 *Class 6*	10–11	310
	11–12	282
	12–13	263
	14–15	247
140–150 *Class 7*	11–12	244
	12–13	224
	16–17	203
	19–20	193

Appendix table 37:Table showing Tensile strength of bamboo.

Source : Mechanical properties of bamboo-research paper
https://www.frontiersin.org/articles/10.3389/fmats.2019.00015/full

CONCLUSION

The maximum tensile stress in the MPH structure as per the analysis is 275 MPa (or N/mm2), under earthquake conditions of Zone V, with an increased load factor of 1.5x

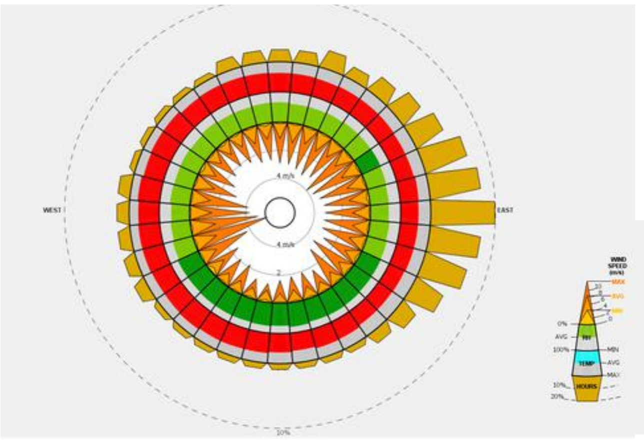
As per the source mentioned, bamboo (Class 6, 140mm dia, 10mm wall thickness) can bear upto 310 MPa

Hence, Class 6, 140mm dia bamboo proves to be earthquake resistant through simulations

12.15 CLIMATE ANALYSIS

PARAMETERS	NAGAON, ASSAM
Koppen Climate Zone	Warm and Humid
Temperature	Dry winter , hot summer
	Annual mean = 23 °C Mean lowest = 16 °C (January) Mean highest = 28 °C (June)
Average Annual Relative Humidity	80.6 %
Wind Speed	Mean highest =4 m/s Mean lowest = 0 m/s
Rainfall	Highest = 570 mm (July) Lowest = 15 mm (December)

Appendix table 37 :Climate of Nagaon Source : Climate consultant and climate-data.org



Appendix Figure 11: Wind wheel

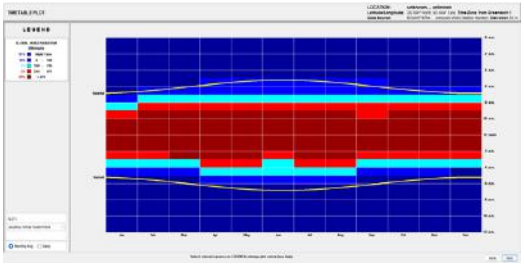


Figure 12 : Comfort graph for Nagaon
Source: Climate Consultant

Figure 13 : Radiation range for Nagaon
Source: Climate Consultant

Inferences,

Mahoney's table 7 showing mean maximum mean minimum temperatures, temperature range, rainfall and of every month. Cooling and dehumidification for > 24°C summers and heating and humidification during winters. < 20 °C

Only dehumidification is needed in the comfort zone.

Eliminating air conditioning	Building design minimizes overheating.
	Window overhangs and verandas
Minimizing summer heat gain	Minimizing the west facing glazing.
	High performance glazing on all orientations.(1500+ hours of internal he gain required during winters.)
Passive ways to ventilate the spaces	Fan forced or indoor air motion can mak seem cooler by 5 degrees or more thus le air conditioning is needed.
	Heat pumps can be an cost effective way dehumidifying for 1000+ hours
	Long narrow building floor plan can help maximize cross ventilation.
	Locating doors and windows on a larger openings facing wind-up.

Figure 14 : showing some adaptive strategies using the psychometric chart and common strategies from the Mahoney's table.

INDICATORS	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
HUMID: H1		*	*	*	*					*	*	*
H2							*	*				
H3					*	*	*	*	*			
ARID: A1	*											
A2												
A3												

Category	Number	Design guidelines
Layout	1	Orintation north and south (long axis east - west)
	2	Compact courtyard planning
Spacing	4	Open spacing for breeze penetration , but protection
Air Movement	6	Rooms single banked, permanent provision for air movement
Openings	9	Large openings, 40%-80%
Wall	12	Light walls, short time-lag
Rain Protection	17	Protection from heavy rainfall necessary
Size of opening	1	Large 40%-80%
Position of openings	6	In north and south walls at body height on windward side
Protection of openings	8	Exclude direct sunlight
	9	Provide protection from rain
Walls and floors	10	Light low thermal capacity
Roofs	12	Light, reflective surface cavity
External features	16	Adequate rainwater drainage

Appendix table 38 : Passive Strategies , Source: Climate consultant

Wind speed maximum February, March, April and September.

Maximum number of hours is from E, NE and SE

sky cover seen is 90% percent and annual mean is 45%.

12.16 HEALTH AND WELL-BEING CALCULATIONS

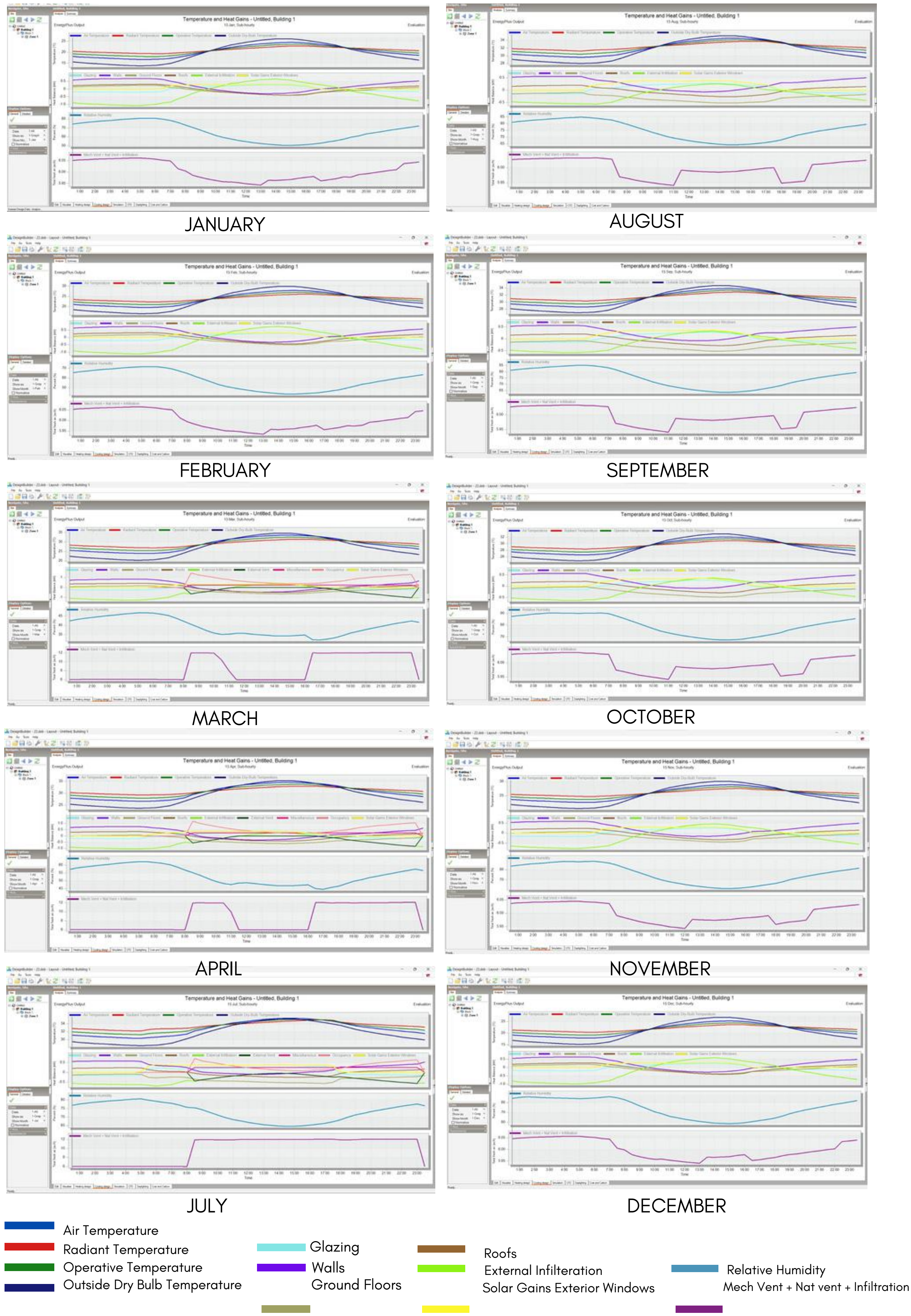


Figure 15: Health and well being calculations

Ventilation rates for each space

Space type	No. of occupant	R_p (l/s.person)	Floor Area (m^2)	R_a (l/s.m^2)	Ventilation rate (l/s)
preschool	30	5	60	0.6	186
junior	40	5	50	0.6	230
middle	40	5	60	0.6	236
high	40	5	60	0.6	236
staff room	12	2.5	30	0.3	39
canteen	480	3.8	100	0.9	1914
canteen - high	250	3.8	50	0.9	995
physics	25	5	70	0.9	188
chem	25	5	70	0.9	188
bio	25	5	70	0.9	188
comp	25	5	70	0.6	167
art room	40	5	70	0.9	263
activity room	40	5	60	0.9	254
library	2000	3.8	300	0.3	7690
hod	2	2.5	15	0.3	9.5
admin	50	2.5	60	0.3	143
mph	1000	3.8	800	0.3	4040
kitchen	10	3.8	30	0.6	56
seminar	400	3.8	200	0.3	1580
r&d	25	5	150	0.6	215

Appendix table 39 : Passive Strategies , Source: Climate consultant

Air Changes

ACH = 60Q/V

Q = 0.3AV

V = 0.6m/s (average)

A = 4 x 2.1 x 3/4 = 6.3 sqm

Q = 0.3 x 6.3 x 0.6

= 1.134 cu m/s

VOLUME = 6 x 10 x 3.9 = 234 cu m

ACH = (60 x Q x 60)/V = (60 x 1.134 x 60)/234

= 0.2907 air changes per minute

= 17.446 air changes per hour

Qmax = 0.3 x 6.3 x 1 = 1.89 cu m/s

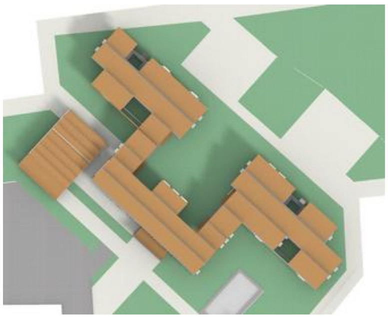
Therefore, ACHmax = (3600 x Qmax)/V = (3600 x 1.89)/234

= 0.485 air changes per minute

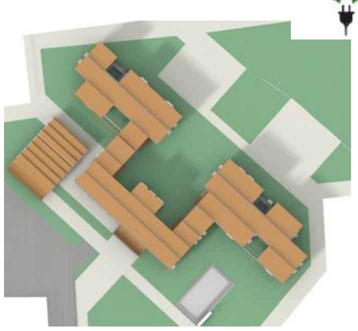
= 29.07 air changes per hour

SPACES	AIR EXCHANGES PER HOUR (AS PER NBC)	AREA OF ROOM	WINDOW AREA	VELOCITY OF WIND	A	Q	VOLUME OF ROOM	ACH ACHIEVED (PER HOUR)	ACH ACHIEVED (ROUND-OFF)
LABORATORIES	6 TO 15	70	8	0.6	6	1.08	273	14.24175824	14
LIBRARY	3 TO 5	300	12.6	0.6	9.45	1.701	1170	5.233846154	5
OFFICES	6 TO 20	15	2.52	0.6	1.89	0.3402	58.5	20.93538462	20
CLASSROOMS	5 TO 7	60	8.4	0.6	6.3	1.134	234	17.44615385	17
TOILETS	6 TO 10	52.5	2.4	0.6	2.4	0.432	204.75	7.595604396	7
CANTEEN	8 TO 12	100	14.7	0.3	11.025	0.99225	390	9.159230769	9

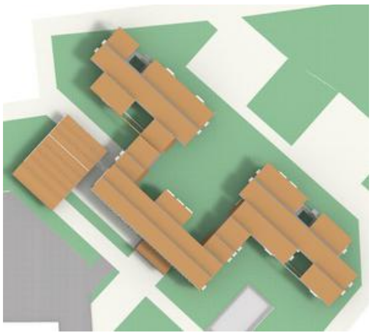
Appendix table 40 : Air changes per hour achieved



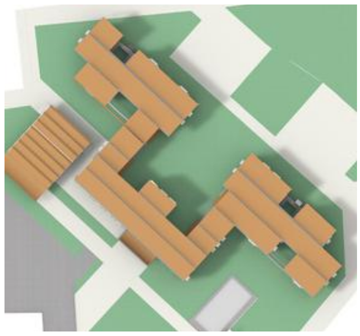
Appendix figure 16 : January - 9 am



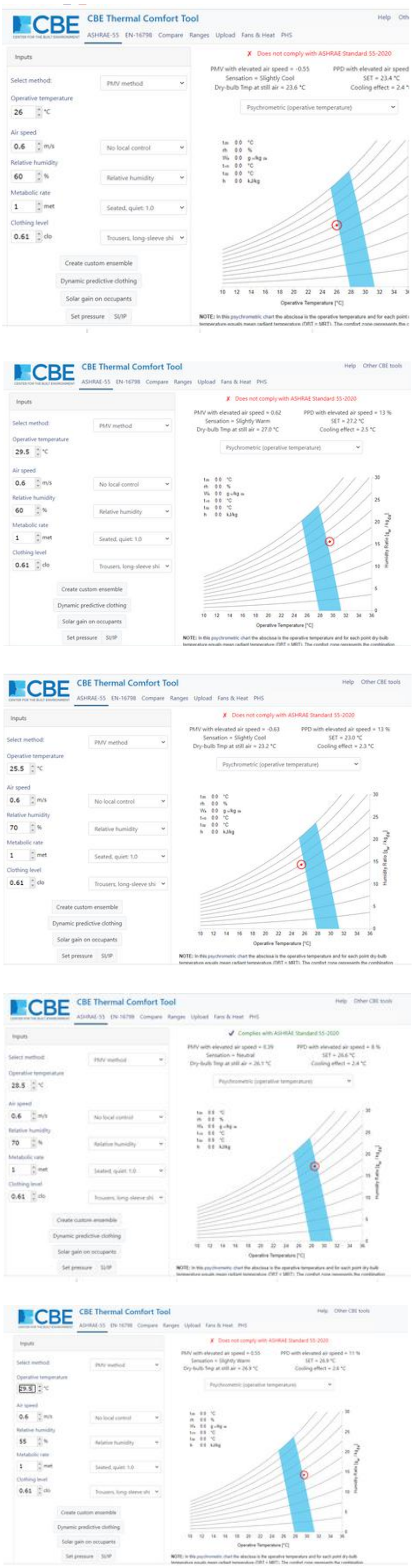
Appendix figure 17 : January - 3 pm



Appendix figure 18 : April- 9 am



Appendix figure 19: April- 3 pm



Appendix figure 20: graphs showing operative temperature and humidity ratio using thermal comfort tool

Thermal comfort analysis

Operative temperature with 90% acceptability for naturally ventilated buildings as per IMAC
According to the adaptive thermal comfort model for air-conditioned areas as per NBC,
Indoor Operative Temperature
= (0.078*Outdoor Temperature) + 23.25
=(0.078*28) + 23.25
=25.434 degrees Celsius
According to the adaptive thermal comfort model for the naturally ventilated area as per NBC,
Indoor Operative Temperature
= (0.54*28) + 12.83
= 27.95 degrees Celsius
Considering the 90% acceptability, the range for India = +- 2.5 degree Celsius

12.17 ADDITIONAL CALCULATIONS

Impulse turbine calculations
Annual amount of water collected: 11135 cubic meters
Average Amount of water available per day = 11135/365 = 30.51 cubic meters
Since there are 2 turbines on site, with each having 3 inlet nozzles, the amount of water available to each nozzle = 30.51/6 = 5.085 cubic meters.
Cross-sectional area of the inlet pipe, A= 0.0095 sqm
Inlet fluid velocity, V= 5m/s
Cross-sectional area of nozzle: 0.0018 sqm
Nozzle fluid velocity: 26.4m/s
Discharge, Q = A*V = 0.0095 * 5 = 0.0475 cubic meters per second
Time taken for discharge of cubic meters of water, t = 5.085/Q = 0.0297 hours
Impact on turbine blade, F = (Fluid density)(Cross-sectional area of jet)((Fluid velocity)^2)
= 1000*0.0018*(26.4^2) = 1254.53N
Torque, T= (Force)*(Turbine radius) = 1254.53 * 0.3 = 376.36Nm
Angular velocity, w = (Torque)/(Moment of Inertia)
i)For steel turbine, Moment of Inertia, I = 1.06 kg*sqm
Thus, w = 376.36/1.06 = 355.056 rad/s
Energy, E = T*w*t = 376.36 * 355.056 * 0.0297 = 3.968 kWh per day on average.

ii)For glass fibre turbine, Moment of Inertia, I = 0.33 kg*sqm
Thus, w = 376.36/0.33 = 1140.485 rad/s
Energy, E = T*w*t = 376.36 * 1140.485 * 0.0297 = 12.75kWh per day on average.
We observe that the glass fibre turbine produces more energy and is thus is more suitable for our purposes.

Swing and Merry-Go-Round Calculations:

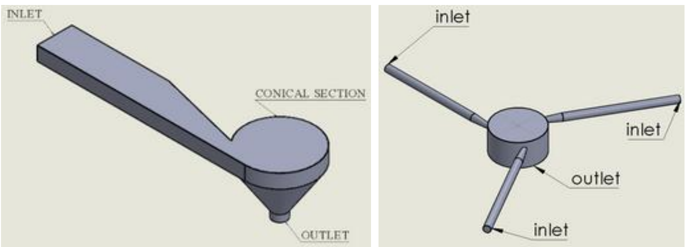
1. Considering that the extreme positions of the swing (-30deg and 30deg) subtend a total of 60deg angle at the shaft,
Total Power Generated, P = (Voltage)*(Current)
= 2* (2V) * (0.3A)
= 1.2 W
Total Energy required to recharge a battery, P’ = (Voltage) * (Capacity)= (1.5V) * (900mAh)= 1.35 Wh
Thus, Time required to recharge a single battery, t = (P’)/(P)= (1.35)/(1.2)= 1.125 hours
Considering a total of 4 swings operating simultaneously, the time required becomes 0.28 hours or 16.8 minutes.

2. Consider a 5kg merry-go-round of diameter 6ft or 1.83m which rotates at a uniform speed of 100rpm and is connected to a dynamo. Assuming that 4 children each of 10kg are riding the apparatus, the total weight becomes 45kg.
Torque on shaft, T = (Weight) * (Radius)
= (45kg * 9.81) * (1.83/2)
= 403.93 Nm
Power generated, P = (RPM) * (Torque) / (9.55e+6)
= (100) * (403.93) / (9.55e+6)
= 4.25 mW
Time required to charge one battery = (P’)/(P)
= (1.35)/(0.00425)
= 317.65 hours
Due to a large amount of time required, charging batteries is not feasible. Thus, it is proposed that small LED bulbs light up when rotated, appealing to the children’s curiosity and fascination while encouraging physical activity.

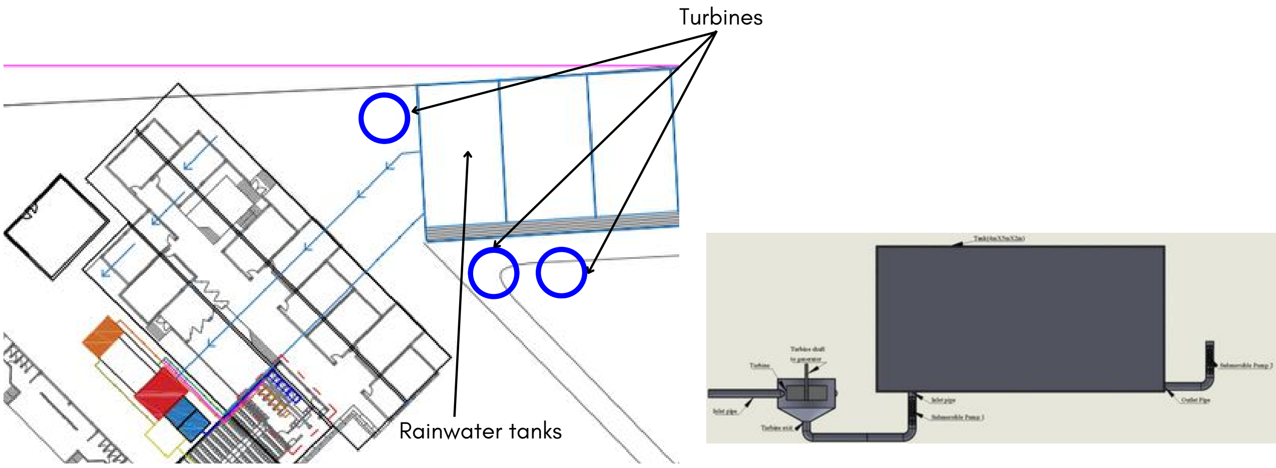
Comparison between Water Vortex and Impulse Turbine

PARAMETER	WATER VORTEX	IMPULSE TURBINE
Diameter	0.5m	0.8m
Depth	0.4m	0.41m
Shaft diameter	50mm	50mm
Turbine diameter	150mm	600mm
Turbine height	0.2m	0.2m
Number of blades	4 (helical)	6 (straight)
Blade thickness	5mm	20mm
Flow rate required	High	Low
Head required	Low	Medium – High
Speed	200rpm (low speed)	1300 rpm (high speed)
Energy generated	3.968 kWh	12.75 kWh
Material used for the turbine	Stainless Steel	Glass fibre
Total capital expenditure on turbine	Rs. 1,13,000 approx	Rs 29,000 approx (lighter)
Generator Cost	Rs. 40,000	Rs. 58,000
Maintenance Cost	Rs. 86,000 per year (turbine)Rs. 20,000 per month (generator)	No maintenance required for the turbine.Rs. 20,000 per month (generator)

Appendix Table 41: Comparison between Water vortex and Impulse turbine



Appendix figure 21: Water vortex(left) and Impulse turbine(right)

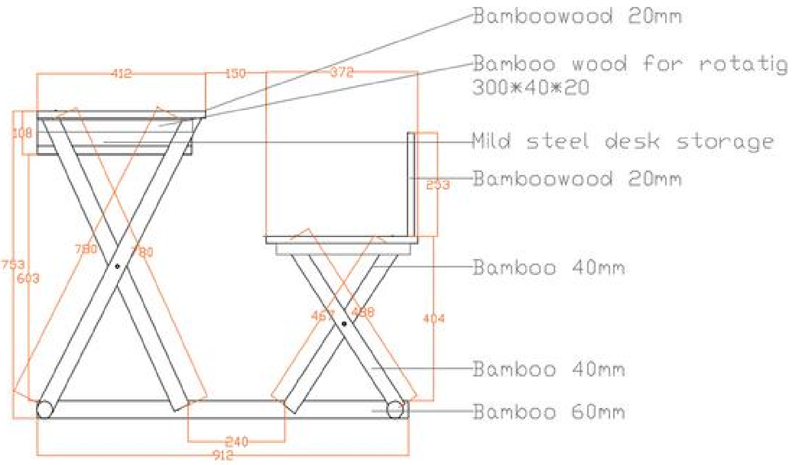


Appendix figure 22: Integration of Impulse turbine with the rainwater harvesting tank and building

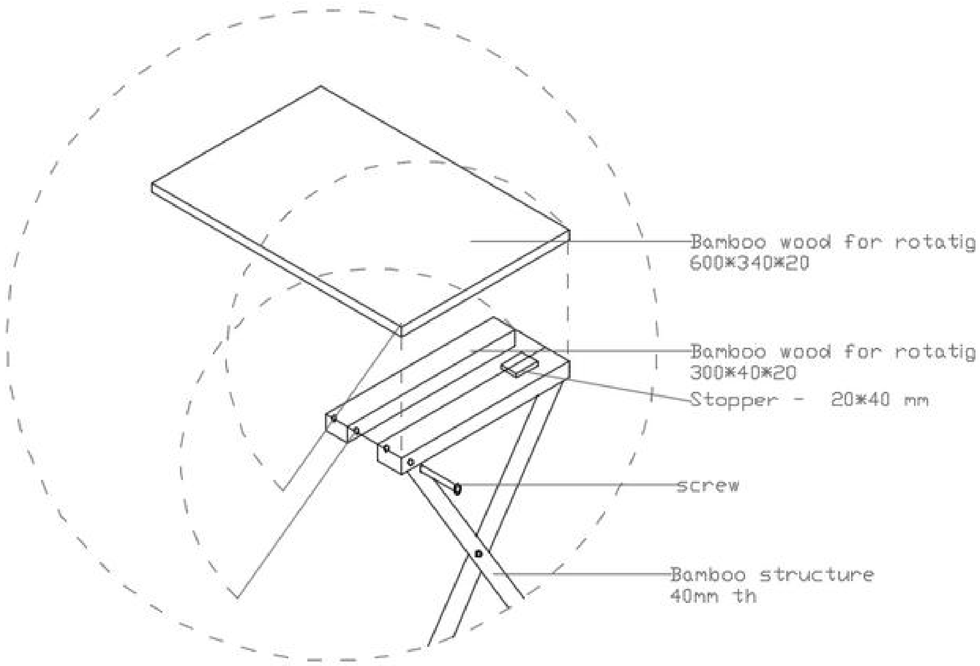
Sl. No.	Particulars	Cost per Unit	Number of units	Total CapEx (INR)	Maintenance Cost (INR)	Lifetime of product (years)	Power Rating	Total Consumption for 8 hours
1	LED Display Screens	3800 / sqft	15 sqm (3 units)	615600	10000 (only when pixel is damaged)	3	600W	4.8kWhr
2	Touch-enabled Smart Board	70000-100000	2	140000-200000	10000 (only when pixel is damaged)	3	150W	1.2kWhr
3	Tablets (AR)	8000-15000	8	64000-120000	-	3	20W	0.16kWhr
4	VR Goggles	50000	8	400000	10000-25000 depending on extent of damage	3	-	14Whr
5	Robotics Kits	Depends on curriculum	30		-	Indefinite	Battery operated	-
6	3D glasses	100	30	3000	-	1	-	-
7	Headphones	5000	30	150000	-	1	-	-

Appendix table 42 : Provision for the future

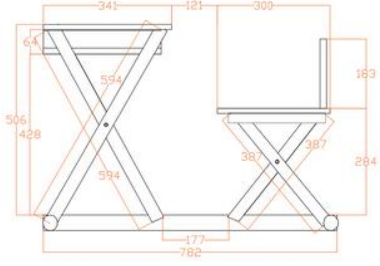
Furniture design calculations
Material used – MS cold rolled tube (3mm)
For one bench 28kgs of MS square tubes is used.
total tube MS used = 28kg * 60rs/kg = 1680
Total MS sheets for joinery = 60 Rs
total cost with nuts and bolts and labor charges = 1680+60+200+60=2000/unit
Bamboo panels calculations
Height of the panel = 1800mm
Width of the panel = 600mm
total length and width = 1800 and 1800 respectively
Material used = Solid bamboo poles of 20mm and 40mm diameter, bamboo mats (22rs/sqft), magnetic sheets (300*300*2mm - 30rs /sheet)
No. of 40 mm diameter poles used = 2
cost = 110/piece
No. of 20mm diameter poles used = 8
cost = 25rs/piece
Bamboo mats and magnetic sheets used = 792rs + 240 Rs
Total = 792+240+400 =1432
Stiches and glue used= 5%
Total = 1460 Rs/ panel
Movable acoustic Partition walls
Aluminum top channel = 125 Rs/feet , aluminum side caps and U-clamp = 125+125=250, saw dust 8rs/kg
Required length per classroom = 4m
Width of panel = 600mm
Length of panel =2100mm
Rice husk required for 1 panel = 2.16 kgs
Cost of rice husk = 8 Rs/kg, total = 17.25 Rs.
Resin required (255/kg) = 0.5kg per panel = 127 Rs
bamboo mats = 308/panel, EPDM rubber seal 60rs
Total =125+125+125+308+308+17.28+17.28+125+60+60+60+16+16= 1362.56 Rs
Labour charges = 30% = 1362+400 = approx 1800 Rs/panel
Installation cost = Total panel cost + Frame 20% =12600 + 20%= approx 16,000 Rs



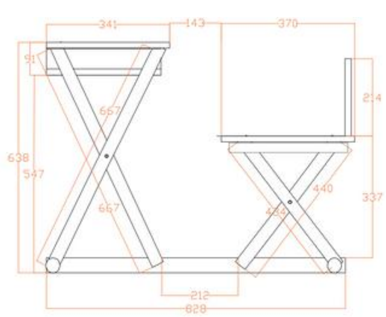
Details of Bench



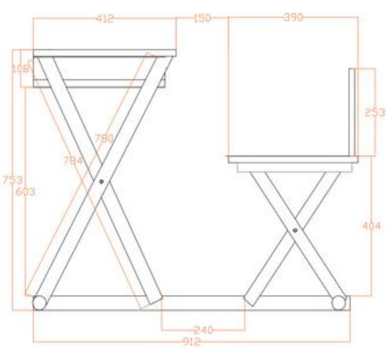
Detail of desk rotating



Age 3 to 6 years



Age 6 to 11 years



Age 11 to 14 years

12.19 GRIHA CRITERIA

Criterion 1: Site Selection

• 1.1.2: The project site is a brownfield site OR a redevelopment project OR there are at least 5 services (from the list given below) within the campus or within 500m walking distance from main entrance of project – **1 point**

Criterion 2: Low-impact design

• 2.1.1: Demonstrate reduction in environmental impact through design by adoption of various passive design and low-impactsite planning strategies – **4 points**

Criterion 3: Design to mitigate UHIE

- 3.1.2: More than 50% of the site surfaces visible to sky (including building roofs but not the landscape area*) are either soft paved/covered with high SRI coating (SRI > 0.5)/shaded by trees/shaded by vegetated pergolas/shaded by solar panels or any combination of these strategies – **2 points**

Criterion 5: Air and water pollution control

• Provision of 3 meter high barricading around the construction area – Mandatory
• Wheel washing facility at the vehicular entrance of the site
• Covering of fine aggregate and excavated earth on site with plastic/geotextile sheets
• Water sprinkling on fine aggregate (sand) and excavated earth
• All diesel gensets on site to have proper chimneys with their outlet facing away from the site
• 5.1.2: Develop and implement a spill prevention plan (to control effects of spill from hazardous materials like bitumen, diesel etc.) on site – **1 point**

Criterion 6: Preserve and protect landscape during construction

- 6.1.2: Increase total number of trees on site by 25% above the pre-construction phase OR Plant 4 trees for every 1 tree cut of the same native/naturalized species – **2 points**
- 6.1.3: Preserve top soil during construction, maintain its fertility (during construction phase) and use for landscape post-construction – **2 points**

Criterion 7: Construction Management Practices

• 7.1.1: Adopt staging during construction on site – **1 point**
• 7.1.2: Adopt strategies to prevent/reduce movement of soil (not top soil) outside the site through adoption of various strategies(like soil erosion channels, sedimentation control etc.) – **1 point**
• 7.1.3: Adopt strategies (at least 3 from the list below) to manage water during construction – **1 point**
• Using gunny bags for curing and using ponding for curing
• Monitoring to avoid leaks and water wastage
• Use of additives to reduce water requirements during curing
• Use of treated waste water/captured storm water
• 7.1.4: A construction waste management plan for segregation of construction waste, its safe storage and on-site/off-site recycling is developed and implemented in the project – **1 point**

Criterion 8: Energy efficiency

- 8.1.2: Peak heat gain through building envelope (for each AC building individually) should meet the GRIHA Building Envelope Peak Heat Gain Factor thresholds – **2 points**
- 8.1.3: Demonstrate that 100% of outdoor lighting fixtures (lamps + lamp housing) meet the luminous efficacy requirements of GRIHA – **1 point** (All lamps + lamp housing must demonstrate luminous efficacy of at least 75 lumens/watt.)
- 8.1.5: Additional reduction in EPI will be awarded points as mentioned below: 50% reduction – **10 points**

Criterion 9: Renewable energy utilization

- 9.1.1: On-site/Off-site renewable energy system installation to offset a part of the annual energy consumption of internal artificial lighting and HVAC systems. 25% – **7 points**

Criterion 11: Achieving indoor comfort requirements(visual/thermal/acoustic)

• Demonstrate that the mean DA requirements (300* lux or more) are met over the total living area for at least 75% of total annual analyse hours (area-weighted) – **4 points**

Criterion 12: Maintaining good IAQ

• 12.1.1: Meet the minimum requirements of a NBC-2005 for quantity of fresh air – 2 points

12.1.2: Monitoring the CO2 temperature and RH at the occupied spaces or at AHUs for the airconditioned spaces – 2 points

Criterion 13: Use of low-VOC paints and other compounds in building interiors

- 13.1.1: Ensure that all interior paints are low-VOC *(as mentioned in the GRIHA manual) and lead-free – **1 point**
- 13.1.2: Ensure that all adhesives and sealants used shall be low-VOC *& that interior composite woodproducts do not use urea-formaldehyde as a bonding resin – **1 point**

Criterion 14: Use of low-flow fixtures and systems

• 14.1.2: Reduce water demand through selection of low-flow fixtures by 50% below the GRIHA base case – **2 points**

Criterion 15: Reducing landscape water demand

- 15.1.3: Reduce landscape water demand by at least 50% from the GRIHA base case – **4 points**

Criterion 16: Water Quality

• 16.1.2: The STP installed on site meets the CPCB norms – **2 points**

Criterion 17: On-site water reuse

• 17.1.1: Demonstrate that the project meets the on-site water reuse requirements (through on-site recycle and reuse of waste water and use of on-site harvested rainwater) in its annual water requirements for domestic use, buildings, landscape and utilities as mentioned below: 80% – **5 points**

Criterion 19: Utilization of BIS recommended waste material in building structure

19.1.1 Minimum 15% replacement of Ordinary Portland cement with fly ash* by weight of cement used in structural concrete – **1 point**
• If replacement is more than 25% – **2 points**
• 19.1.2 Minimum 40% composition of building blocks/bricks by fly ash* by volume, for 100% load bearing and non-load bearing masonry walls – **2 points**
• 19.1.3 Certify minimum 15% replacement of Ordinary Portland cement with fly ash* in plaster/masonry mortar – 1 point
• If replacement is more than 25% – **2 points**

Criterion 20: Reduction in embodied energy of building structure

- 20.1.3: Demonstrate reduction in combined embodied energy of load-bearing structure and masonry walls by at least 30% below the base case – **4 points**

Criterion 21: Use of low-environmental impact materials in building interiors

- 21.1.1: Project demonstrates that at least 25% of all materials (calculated by surface area) used for building interiors* meets the GRIHA criterion low-impact material requirements – 1 point

Criterion 22: Avoided post-construction landfill

- 22.1.1: Provide infrastructure (multi-coloured dustbins/different garbage chutes) to building occupants
- to ensure segregation of waste at source
- 22.1.2: Provide dedicated, segregated and hygienic storage spaces in the project site to store different
- wastes before treatment /recycling
- 22.1.3: Provide contractual tie-ups with waste recyclers for safe recycling for recyclable wastes like
- metal, paper, plastic, glass etc.
- Together – **4 points**

Criterion 23: Treat organic waste on site

- 23.1.1 Implement strategies to treat all organic (kitchen and landscape) waste on-site and to convert it into a resource (manure, biogas etc.) – **2 points**

Criterion 25: Design for Universal Accessibility

- 25.1.1: Compliance with National Building Code norms on Requirements for Planning of Public Buildings Meant for Use of Physically Challenged – **2 points**

Criterion 26: Dedicated facilities for service staff

- 26.1.1: Provide dedicated resting roomsfor the service staff on site – **1 point**

Criterion 27: Increase in environmental awareness

- 27.1.1: Adopt measures to create environmental awareness – **1 point**

Criterion 31: Innovation

• Net-Zero Energy/Water – **1 point**

TOTAL POINTS - 81
Our building achieves a **GRIHA 4 - Star** Rating

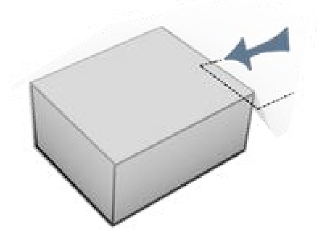
12.20 LIST OF INPUT AND OUTPUT PARAMETERS

Input Parameters	Units	Proposed Design Values
General		
Building Area	m²	8072
Conditioned Area	m²	1210
Electricity Rate	INR/kWh	8.02
Natural Gas Rate	INR/GJ	NA
Building Occupancy Hours	-	8 am to 5 pm
Average Occupant Density	m² / person	4.036
Internal Loads		
Interior Average Lighting Power Density	W/m²	TBA
List of Lighting Controls	-	–
Average Equipment Power Density	W/m²	TBA
Minimum OA Ventilation (Building Average)	m/s	0.6
Envelope		
Roof Assembly U value	W/m².K	0.28
Roof Assembly SRI		TBA
Average Wall Assembly U value	W/m².K	0.28
Window to Wall Area Ratio (WWR)	%	N(40), S(20), E(10), W(8) - 19.5%
Windows U value	W/m².K	1.4
Windows SHGC		0.47
Windows VLT	%	59%
Infiltration Rate	ac/h	TBA
Describe Exterior Shading Devices		Refer pg 15
HVAC System		
HVAC System Type and Description	-	VRV+DOAS System (pg 30)
Describe Mixed mode strategy in operation/controls of AC and windows	-	Refer pg 41
Heating Source	-	NA
Heating Capacity	kW	NA
Heating COP		NA
Cooling Source	-	VRV System
Cooling Capacity	kW	TBA
Cooling COP		3.67
Operation Hours		11 hrs/day
Heating Set Point	°C	NA
Cooling Set Point	°C	27.4
Relative Humidity Setpoint		NA
Service Hot Water		
SHW Type and Description	-	Heat Pump (Refer pg 26)

Output Parameters	Units	Proposed Design Values	
Proposed EUI (Total)	kWh/m²/ yr	**26.5**	
EUI Breakdown by End Use			
Heating	kWh/m²/ yr	**NA**	
Cooling	kWh/m²/ yr	**1.38**	
Fans	kWh/m²/ yr	**0.94**	
Pumps	kWh/m²/ yr	**0.75**	
Heat Rejection	kWh/m²/ yr	**NA**	
Service Hot Water	kWh/m²/ yr	**0.24**	
Lighting	kWh/m²/ yr	**0.34**	
Equipment	kWh/m²/ yr	**2.55**	
Total Envelope Heat Gain (Peak)	W/m²	**TBA**	
Cooling Load of Conditioned Area	SF/ Tr	**302.88**	
Building Electric (Peak)	W/m²	**TBA**	
Annual Operating Energy Cost	INR/m²	**Rs 446/m2** (this value does not apply to our case as we are not buying any energy)	
Annual Unmet Hours	-	**Daylight - 547/2187, Wind - 0/2187**	
Cooling Capacity	Tr	**42.93**	
Annual Hours of Comfort without Air Conditioning		**2187/2187 hours for 84% (6860 m2) of the building**	
Monthly Energy Performance		**Generation**	**Consumption**
Jan	kWh	**18290**	**20015**
Feb	kWh	**21033**	**18981**
Mar	kWh	**21948**	**22698**
Apr	kWh	**21948**	**18611**
May	kWh	**21948**	**17362**
Jun	kWh	**3658**	**16050**
Jul	kWh	**19204**	**16401**
Aug	kWh	**21033**	**16623**
Sep	kWh	**21948**	**17178**
Oct	kWh	**13717**	**20247**
Nov	kWh	**20119**	**20176**
Dec	kWh	**17375**	**18147**

Appendix table : Input and output parameters

12.21 DESIGN PROCESS



Building block oriented 30 deg. to wind direction for effective natural ventilation

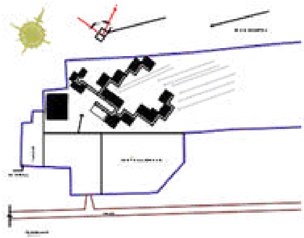
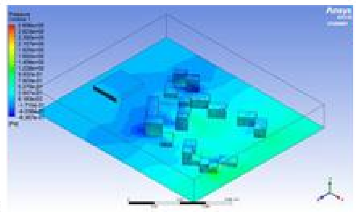
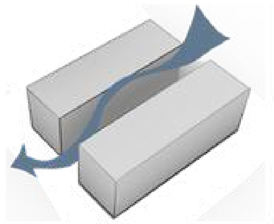


Figure 11a :Initial Iteration 1



Buildings are at a 30 degree inclination to the wind direction



Channelizing wind through built masses (wind funneling for greater velocity)

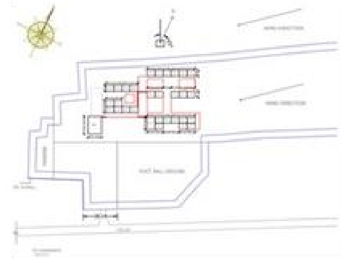
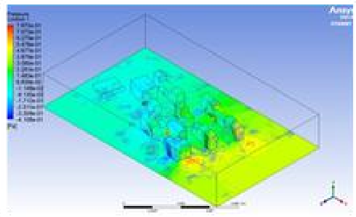


Figure 11b :Initial Iteration 2



Buildings are parallel to the wind direction

12.1 ITERATION 1

Courtyards help in cross - ventilation and help in maintaining the comfort conditions for the classrooms

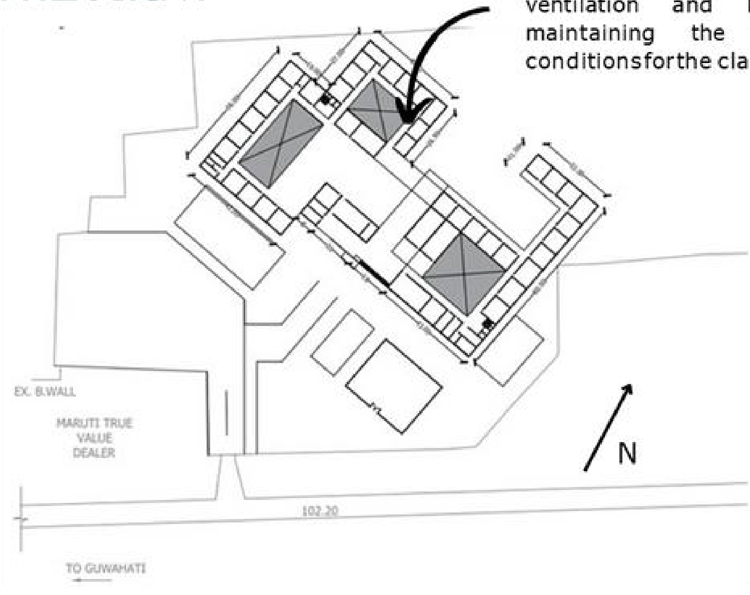
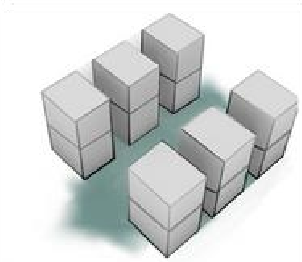
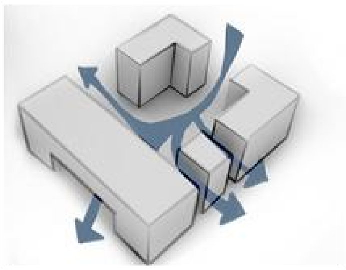


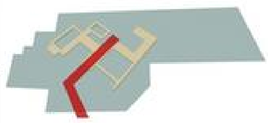
Figure 12.1a :Plan - Iteration 1



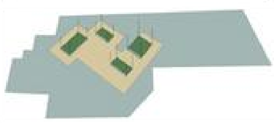
Intermediate breakout spaces for better learning experience and interaction amongst students



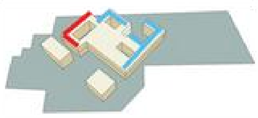
A combination of breakout space sand wind funneling for better user experience



East-West orientation increases ventilation and day light access

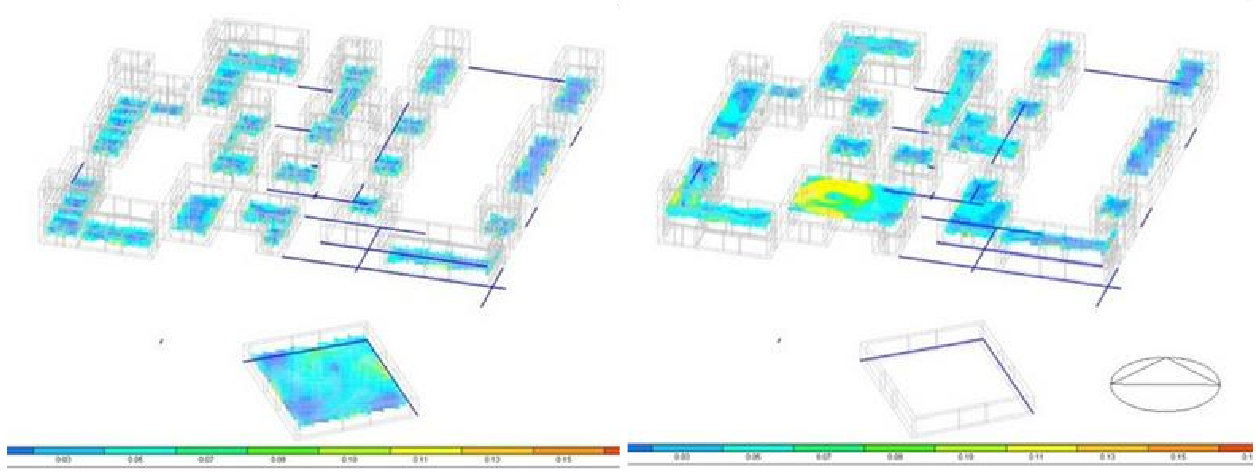


Creating courtyard & interactive spaces between spaces



Classrooms are placed on the periphery around the courtyard, services and admin (mechanically ventilated) are in the wind shadow region

Appendix figure : Design process

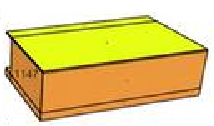


Appendix figure : Process simulation

The following below images shows the solar radiation from the surface of building through out the year. Surface include roof, walls and floor slabs. Software used for this particular simulation was CLIMATE STUDIO (1.8.8244.25334)

•Material chosen for this particular simulation are-Bamboo for walls, Concrete for floors, plinth and roof.

•On an average solar radiation was observed to be around 659 kWh/m2- Year, March and May had the highest values compared to other months.



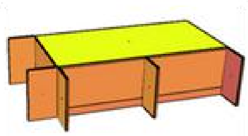


Fig c:Block model with vertical shading. Solar radiation values are :
South:1113kWh/m2
East:1084 kWh/m2

- On simulating a block model, with multiple shading devices(Louvres-Horizontal, vertical and combination of both) for solar radiation, optimum passive strategy was to provide horizontal shading device for south façade(as shown in fig b) and vertical shading device for east façade(as shown in fig c).

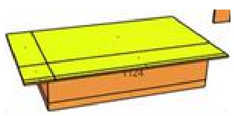
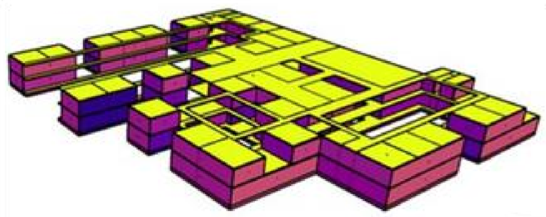
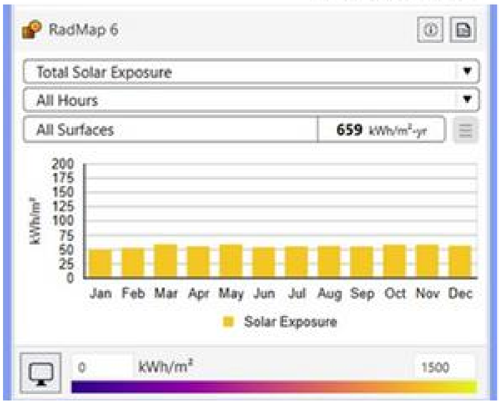


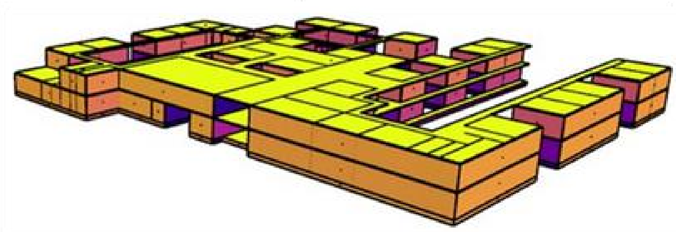
Fig b: Block model with horizontal shading. Solar radiation values are:
South:1090 kWh/m2
East:1124 kWh/m2

Fig d: Block model with combination of horizontal and vertical shading.
Solar radiation values are:
South:1121kWh/m2
East:1129 kWh/m2



- North and West façade has low solar radiation varying from 550 to 780 kWh/m2- Year





- South and east facing surfaces had maximum radiation ranging from 1000-1190 kWh/m2- Year, provision of corridors and shading devices reduced the values to as low as 300 to 400 kWh/m2- Year.

Appendix figure : Process simulation 2

13. LETTERS OF CONFIRMATION

13.1 PROJECT PARTNER LETTER

Gyandeep Foundation

Antaraa Tower, Danish Road, Pan Bazar, Guwahati-781001 (Assam)
Phone No - 0361 - 2632883 Fax - 0361- 2603454

Date : 08.09.2022

To,
The Director
Solar Decathlon India

Dear Sir,

This is to inform you that our organization GYANDEEP FOUNDATION, Guwahati, (Assam) has provided information about our DPS Nagaon, Deodhar, Nagaon, (Assam) project to the participating team led by RV college of Architecture, so that their team GREEN COLLARS may use this information for their Solar Decathlon India 2022-23 Challenge entry.

As a Project Partner to this team for the Solar Decathlon India 2022-23 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, resilient and affordable solution this student team proposes and the innovation that results from this. We intend to have a representative from our organization attend the Design Challenge Finals event in April, if this team is selected for the finals.

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

With warm regards,

Name of Representative: ASHWINI CHHAWCHHARIA

Designation: Vice -President

Email: ashwini@karnak.in

Phone: 70026 04939

13.2 INDUSTRY PARTNER LETTER

ZERUND

ZERUND MANUFACTURING PVT. LTD.
HOUSE NO. 10, SEWALI PATH, HATIGAON, GUWAHATI 38, ASSAM
GSTIN:18AABCZ2574J1ZX

Date :- 16- 02-23

To,
The Director,
Solar Decathlon India.

Dear Sir,

This is to inform you that our organisation, Zerund Manufacturing Pvt. Ltd., is collaborating with the participating team led by RV College of Architecture on an Educational Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be assisting the team to achieve their goal of a Net Zero Energy building, by advising them on existing strategies and practices that can be used for the same, as well as guiding them to innovate and devise new strategies that better suit their building.

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

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

With warm regards,

Name:- Mousum Talukdar
Designation :- Director
Name of the Organisation:- Zerund Manufacturing Pvt. Ltd.
Email:- mousum.talukdar@zerund.com
Phone:- 7002231943

Zerund Manufacturing Pvt. Ltd.
Mousum Talukdar
Authorized Signatory

13.2 INDUSTRY PARTNER LETTER

CENTRE FOR GREEN BUILDING MATERIALS & TECHNOLOGY
7, Aditigreenscapes, No.20, Venkateshpura, Srirampura, Sampigehalli Road
Bangalore - 560 064, Karnataka, India. Tel.: +91 80 22792658, 22712426, cgbmtblr@gmail.com
www.cgbmt.net

CGBMT

Ref.:

Date: 15.04.2023

To,
The Director,
Solar Decathlon India.

Dear Sir,
This is to inform you that our organization, **Centre for Green Building Material and Technology** is collaborating with the participating team led by RV College of Architecture on an Educational Building project for their Solar Decathlon India 2022-23 competition entry.

The nature of our collaboration will be assisting the team to achieve their goal of a Net Zero Energy building, by advising them on existing strategies and practices that can be used for the same, as well as guiding them to innovate and devise new strategies that better suit their building.

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,

Ar. Neelam Manjunath
CEO, Founder and Managing Trustee,
Centre for Green Building Materials and Technology,
Bangalore.

13.3 LETTERS FROM INSTITUTIONS

RV Educational Institutions ®
RV College of Architecture ®
Affiliated to Visvesvaraya Technological University, Belagavi
Approved by Council of Architecture (COA), New Delhi

Date: 21-02-2023

BONAFIDE CERTIFICATE

This is to certify that the bearers of this letter are bonafide students of R.V.College of Architecture (RVCA), Bengaluru currently studying in VI & VIII Semester B. Architecture course.

The B. Architecture course is of 5 Years duration affiliated to Visvesvaraya Technological University, Belagavi.

This certificate is issued only for the purpose to take part in "Solar Decathlon Competition", on request of the Green Collars Team.

Dr. O P Bawane
Principal
PRINCIPAL
R V COLLEGE OF ARCHITECTURE
BENGALURU - 560 109.

List of the Students:

1. Ms. Sanya Gupta - 1RW19AT091
2. Ms. Priyesha Anantharamakrishnan - 1RW19AT073
3. Ms. Polimera Srinidhi - 1RW19AT067
4. Ms. Anisha Dara - 1RW19AT013
5. Mr. Jatin E. - 1RW19AT047
6. Ms. Saakshi Patil - 1RW19AT081
7. Ms. Shivani Goud - 1RW19AT096
8. Mr. Madan Shekhar - 1RW19AT055
9. Mr. Pratham Rathi - 1RW20AT073
10. Ms. Navya U B - 1RW20AT059
11. Ms. Manasa Rao - 1RW20AT52
12. Mr. Aniruddh Bajpai - 1RW20AT011

Site CA-1, Banashankari 6th Stage, 4th Block Near Chikagowdanapalya Village, Off, Vajarahalli Main Road, Bengaluru - 560109, Karnataka, India
+91-97422 75212
rvca@rvei.edu.in
www.rvca.edu.in

Go, change the world

13.3 LETTERS FROM INSTITUTIONS

RV UNIVERSITY
Go, change the world
an initiative of RV EDUCATIONAL INSTITUTIONS

RV Vidyaniketan, 8th Mile, Mysuru Road, Bengaluru, 560059, India
Ph : +91 80 68199900 | www.rvu.edu.in

Date: 21.02.2023

BONAFIDE CERTIFICATE

This is to certify that Ms. Dhatri N K , D/o Mr. Nandakishore K is a bonafide student at RV University. She has been admitted in academic year 2021-22 for Bachelor of Design (B.Des) in the School of Design & Innovation. Presently, She is pursuing her 2nd year IV Semester in Spatial and Interior Design Specialisation 4-year undergraduate programme (B.Des).

This Certificate is issued at the request of the Green Collars Team for the purpose of participating in the Solar Decathlon India Competition.

RV University Bengaluru-59.

Vinay Mundada
Dean – School of Design & Innovation

RV College of Engineering

Autonomous Institution Affiliated to Visvesvaraya Technological University, Belagavi

Approved by AICTE, New Delhi, Accredited by NAAC, Bengaluru

TO WHOMSOEVER IT MAY CONCERN

This is to certify that the below-mentioned students are bonafide students of R V College of Engineering and currently studying in V Sem B. E.

Bachelor of Engineering is a 4 Year duration course, and R V College of Engineering is affiliated with Visvesvaraya Technological University, Belagavi, Karnataka (India).

This certificate is issued at the request of the Green Collars team for the purpose of the Solar Decathlon India competition.

Student:

Rakesh Shankar - 1RV20ME083

5TH SEMESTER, MECHANICAL ENGINEERING DEPARTMENT

Principal Signature: 22/2/23
PRINCIPAL
RV COLLEGE OF ENGINEERING
BENGALURU - 560 059