Solar™ Decathlon India

Final Design Report

April 2023

Educational Building

Team YUKTHA

yuktha

Jawaharlal Nehru Architecture and Fine Arts University

School of Planning and Architecture, Hyderabad

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Response to the Reviewer's Comments

Reviewer 1

Section	Reviewer's comment	Our response
Energy Performance	You have to show evidence that your selected strategy is able to reduce EPI as well as can maintain thermal comfort in all the occupied spaces for the hours they are occupied.	We have addressed this on page 23.
Engineering and Operations	For structural system, you have presented your design strategy however, calculation and justification is missing (for e.g., load calculation to ensure structural safety). you have not covered all the aspects of the contest requirements..	We have provided these on page 21.
Affordability	You should have provided calculations and some narrative explanation about cost effective strategies that you are applying in your design. There's no detail on rightsizing, use of repurposed materials (if any), and other construction strategies that help you reduce the overall cost compared to baseline.	We have mentioned these in page 29.
Innovation	It is not clear what is the innovation you are bringing? The section do not follow and fits the criteria and requirements of innovation contest based on your current narrative. Read the competition guide for contest requirement and deliverable guideline.	we have addressed this in page 30
Health and well-being	You could have provided more details and analysis on thermal comfort, ventilation and air quality which is part of the contest requirements. You should consider a thermal comfort model which you are trying to achieve and a set-point temperature range that you want to maintain inside the spaces	We have mentioned these in the Appendix and page 19.
Value Proposition	The initial cost for proposed design is also higher than the baseline and you should provide well rounded justification for this that will help your client to invest in your proposed idea. This section can be improved if you use compelling narrative to justify (with calculations) why your client should invest along with financial implications.	We have mentioned these in page 33

Response to the Reviewer's Comments

Reviewer 2

Section	Reviewer's comment	Our response
Energy Performance	You have to show evidence that your selected strategy is able to reduce EPI as well as can maintain thermal comfort in all the occupied spaces for the hours they are occupied.	We have addressed this on page 23.
Engineering and Operations	For structural system, you have presented your design strategy however, calculation and justification is missing (for e.g., load calculation to ensure structural safety). you have not covered all the aspects of the contest requirements..	We have provided these on page 21.
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Executive Summary

Team Yuktha comprises of 13 students from the School of Planning and Architecture, JNAFAU, Hyderabad who came together to work on the net zero energy building challenge by Solar Decathlon India 2022.

We are enthusiastic students who wish to change the way buildings are designed by participating in this challenge. We are working on designing a net zero enrgy and water Educational building located in Mumbai as part of a larger development by partnering with Lodha group.

For arriving at the final design, we tried out multiple iterations by dividing ourselves into 6 groups of 2 people each. We then listed out the advantages and disadvantages of each iteration and mapped out the process for finalising one iteration. This enabled us to take the correct design decisions.

We followed a meticuluous process of design that combined all aspects at the same time. Our analsysis of various parameters is reflected in the final outcome.

The final iteration was developed further according to the criteria set by the 10 contests. We aimed to create a unique school environment which would promote it's value. We proposed innovative solutions for the learning pedagogy, rainwater harvesting strategy, and the facade/ window details. For reducing energy consumption, we designed spaces to bring in natural light for most parts of the occupied time. The building envelope was optimized by using glass with effective thermal properties on particular faces of the building. The classrooms have air conditioning which operates in a mixed mode. It is switched off when natural ventilation is available for providing indoor comfort. An EPI of 68 was achieved with the air conditioning system whereas without the air conditioning for classrooms, the EPI reduced to 43.2. The structural system for the building is designed to resist earthquake and wind loads. Simulations and testing of the structure helped in understanding the loads acting on the building. Spaces are also designed to be aesthetically pleasing by providing courtyards, interaction spaces, balconies, landscaped seating etc. To reduce the carbon emissions and embodied carbon from building materials and construction, we proposed to use natural low carbon materials for building elements other than the structural system. Recycled plastic, bamboo and various other materials are used for additional ornamentation to enhance the overall experience of being in the school.

Team Summary

Team name : Team Yuktha

Institution name : Jawaharlal Nehru Architecture and Fine Arts University

Division : Educational Building

Team Members

Yateendra.T
Architectural Design & modelling
Team Lead
Architecture student

Pranav.R
Energy Performance & Simulations
Co-Team Lead
Architecture student

Chakravarthy.K
Modelling
Team member
Architecture student

Devendar.B
Innovation
Team member
Architecture student

R.Rohan Kumar
Water performance
Team member
Architecture student

Nikhil.N
Affordability
Team member
Architecture student

Anjana.D
Emboided Carbon
Team member
Architecture student

Reesha.K
Research & Lighting and services
Team member
Architecture student

Sripriya.G
Passive Cooling Strategies
Team member
Architecture student

Jayashree.P
Resilience
Team member
Architecture student.

Akshaya.M
Thermal Comfort
Team member
Architecture student.

Deepika
Engineering & Operations
Team member
Architecture student

Approach

Team Yuktha comprises of 13 students from the School of Planning and Architecture, JNAFAU. We are a team of passionate individuals with each member having a variety of skillsets which can be put to use with the progressing stages of the competition. We started off by dividing work among ourselves such that each person gets to work on a topic that they have an edge in.

We also ensured that each of us would learn something new by selecting a topic that they are interested in. We often faced challenges in terms of differences in opinions between our team members but we came up with our final outputs after extensive discussions and deliberations which led to a mutual understanding between everyone. We also believed that discussions and inputs from other teams and faculty would benefit us. Therefore, we prepared multiple drafts before finalising on any particular idea. Design is subjective and our approach leans towards a method of dialogue and discussions among our team members as well as others to take decisions and arrive at a solution.

Institution

With a heritage of more than 70 years, the present university of Jawaharlal Nehru Architecture and Fine Arts University (JNAFAU) was established by Act of Andhra Pradesh State Legislature No. 31 of 2008. The university offers undergraduate, post-graduate and PhD research programs. It has two different colleges: the School Of Planning & Architecture (SPA) and the College of Fine Arts (CFA).SPA offers 5 UG programs (Architecture, Planning, Interior Design.

Faculty Lead and and Faculty Advisors

Aditya Singaraju
[B. Arch M.Des, Product design]
Assistant Professor JNAFAU
Faculty lead

Ch. Sharmila Durai
[B.Arch, M.Arch(ED)]
Associate Professor JNAFAU
Faculty Advisor

P. Uday Shanker
[B.Arch M.URP]
Assistant Professor JNAFAU
Faculty advisor

Kartik Mahon
[B.Arch, M.Design]
Assistant Professor JNAFAU
Faculty advisor

Tools used for design

Modelling tools

- AutoCad
- Sketchup
- Rhino, Grasshopper
- Revit

Analysis tools

- Climate Consultant
- Climate Studio
- Design Builder
- Ladybug tools for Grasshopper
- Vayu Pravah
- Edge app - buildings
- Resist software(earthquake resistance simulation)

Presentation tools

- Canva
- Procreate
- Adobe Indesign
- Adobe Photoshop
- Adobe Illustrator

Project Summary

Project Name :- LODHA CODENAME

Project Partner:- LODHA GROUP

About Lodha group

Lodha Group or Macrotech Developers (formerly known as Lodha Developers) is an Indian multinational real estate company headquartered in Mumbai, India
Lodha Group was established by 1980 by Mangal Lodha, a businessman and politician, who serves as Member of Legislative Assembly.
They been able to create landmark developments across residential, retail & office spaces, winning the trust and appreciation of our patrons time and again.They started this journey by establishing schools in their developments with the intention of imparting quality education to our future citizens and empowering them to become leaders of tomorrow.

Description of the Project

The Project is situated in Dombivili, in the Thane district, which is near the city of Navi mumbai.
The site for the school is a part of a larger development consisting of residential, commercial and other public infrastructure.
The vision is to design and create a successful school which has an institutional identity, and which supports the residential development in Upper Thane.

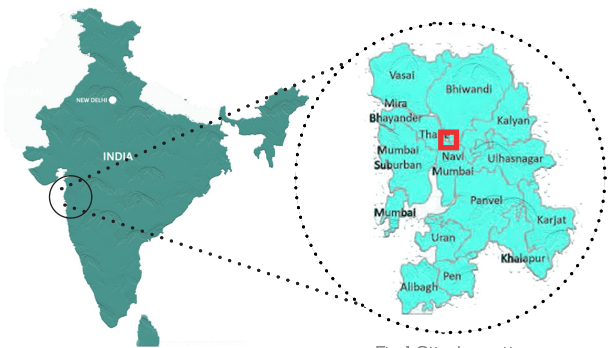


Fig.1 Site Location

Based on the Project Partner's specifications, the building should look like an institutional building. The environment should be conducive for research, learning, interaction and play. The building should be such that students and teachers should feel proud, safe and happy to be associated with their centre of learning.

Areas :-

Total Site Area(Excluding Playground)	6,200 SQM
Total Built-Up Area	10683.85 SQM

Energy Performance Index Goal

We aim to reduce the energy consumption by using passive design strategies and minimising HVAC use.

EPI target - 55 KWh/m² per year (updated from EDGE App calculations)

EPI achieved through simulation - **56.66 KWh/m² per year** (with air conditioning for classrooms)

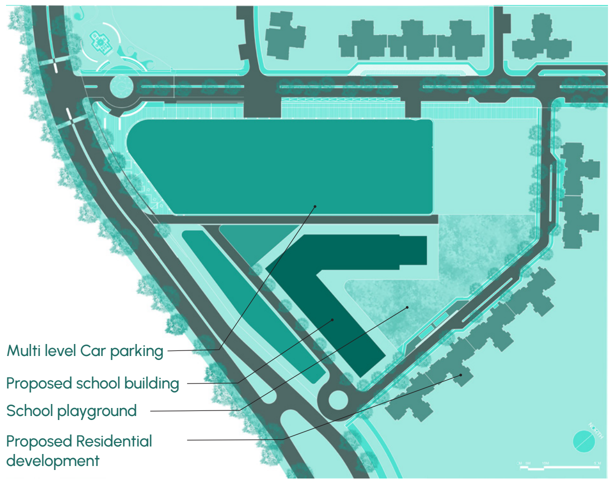


Fig.2 Proposed Site Plan by Project partner

Preliminary estimate of on-site renewable energy

Assuming that we use more than 70% of the rooftop area for Solar panels to generate Solar energy, the area of the roof would be 2,500sqm x 0.7 = 1750 sqm.
Considering solar panels of 465 Watts, annual energy generated by each solar panel = 465 x 2856 hours (assuming 2856 hours of sunshine in India in a year) = 1328.04 kWh/year
Each solar panel is assumed to take up 2.2m^2 of area. So, number of solar panels = 900
Therefore, the annual on site renewable energy potential using solar panels would be approximately **6,01,323 kWh/year.**

On site renewable energy potential using Biomass energy
The total amount of energy generated through biomass - 3801.2 kWh/year(Calculated from Solar decathlon india's project data form). Biomass would be procured from surrounding residential buildings and the waste from the school itself.

Preliminary Construction Budget

Target Project Cost Estimate (Rs 2825per Sqft. Of BUA are including infra around school)

Items	Cost per sq. ft. of BUA (INR)
Civil +Structure	1100
MEP+OEMS	475
Façade	275
KCA +Finishing	475
Infra (including Parking and Landscape)	300
Consultancy	100
Cm control/common project expense	100
Total	Rs 2825

Table 1

Timeline of the project

The project is expected to start after the month of January 2023.

Special requirements of the project partner

- Closed security fence on all the 4 sides of the school plot.
- RCC frame structure to be designed for the school building.
- Elevators should be able to accommodate a wheelchair.
- Usually the student's dispersal happens in 2 modes- Pedestrian and Bus. And there are separate dispersal points. And both exits should not cross.
- Gasbank (as per area of project), DG/CSS as per requirement, UGT + Pump room, Garbage room, Rainwater harvesting strategy, Solar panels on the building terrace, Compost pit to be provided.
- All staircases to have fire rated doors,panic bars and necessary hardware.
- False ceiling to be considered at Ground floor lobby ,Passages, Multipurpose hall etc andSpaces where services/cables/sprinklers are going through.

Goals

ARCHITECTURAL DESIGN

- Recreational spaces
- Interactive furniture and elements
- Daylighting, Biophilic design
- Orientation - Creation of shaded open spaces
- Modular construction
- Reuse of construction materials on site and usage of existing elements on site.

ENGINEERING AND OPERATIONS

- Security and Surveillance of spaces
  Reducing energy consumption by 10-15% with Building Automation and Internet of Things(IoT)

HEALTH AND WELL BEING

- Indoor Air Quality - Aiming to maintain fresh air requirements of 8litres per person per head in classrooms and learning areas.
- Stress-free environment
- Peace and Tranquility in spaces with good Acoustic comfort in spaces.

AFFORDABILITY

- Targetting to reduce Operational Costs by 30%
- Cost effective Structural design
- Cost effective and recyclable materials

ENERGY PERFORMANCE

- Achieving low EPI values for the building - **50-60**
- Reduction in energy consumption by 25% by minimizing HVAC systems and employing passive design strategies.

RESILIENCE

- Resilience against natural calamities like floods, Earthquakes etc. by using flexible and modular construction techniques for easy reconstruction and disaster recovery.

CARBON EMISSIONS

- Aiming to reduce carbon emissions by 30% which would include operational carbon emissions as well as embodied carbon emissions.

WATER PERFORMANCE AND WASTE PROCESSING

- Reducing dependence on piped water supply by 50%.
- Waste management for proper recycling of waste materials.

RENEWABLE ENERGY SYSTEMS

- Aiming to generate reneweable energy equal to total energy consumption to achieve net-zero energy design.

Strategies

ARCHITECTURAL DESIGN

- providing breakout spaces to engage students and promote interactions.
- creating interesting staircase designs to reduce energy consumption due to lifts,elevators and mechanical systems.
- Orienting building to enable maximum natural ventilation and indoor comfort.

ENGINEERING AND OPERATIONS

- rightsizing of HVAC systems for optimum energy consumption.
- using building automation systems for managing energy consumption by sizing mechanical systems according to occupancy and usage.

HEALTH AND WELL BEING

- using strategies for dehumidification and thermal heat gain.
- acoustic ceilings, acoustic wall panels for creating comfortable spaces like classrooms, multipurpose halls etc.

ENERGY PERFORMANCE

- Aiming to achieve an EPI value of 53 $kWh/m^2/yr$ by using various strategies of renewable energy systems, rightsizing of hvac and mechanical systems,

AFFORDABILITY

- energy efficient measures to ensure savings of upto 20%
- reducing floor plate area and construction costs. combining spaces with similar functions.

RESILIENCE

- safety and evacuation techniques for resilience.
- providing seismic gaps for long and linear building blocks.

CARBON EMISSIONS

- using materials with low carbon emissions factor to reduce total emissions of the building
- Use of recyclable materials and low embodied carbon.

WATER PERFORMANCE AND WASTE PROCESSING

- rainwater harvesting to reduce dependence on municipal/piped water supply.
- Modular rainwater filtration systems to use maximum amount of rainwater collected on site.
- Waste segregation into wet waste and dry waste. Using waste for biomass energy generation and wet waste for manure.

RENEWABLE ENERGY SYSTEMS

- Using rooftop solar panels to gather maximum solar energy.
- Biomass energy generation through recycling of food waste from surrounding residential apartments as well as the school building.

Design process

The below flow chart shows our approach for arriving at the final design.

01 CLIMATE ANALYSIS
We studied the climate of the region and analysed various data that would enable in devising design strategies

02 PRE-DESIGN ANALYSIS
Involved with research and analysis of existing buildings, precedents to study strategies.

03 DESIGN CONCEPTS AND ITERATIONS
Developing design concepts and iterations. Incorporating various design ideas in the building forms.

04 CHOOSING AN ITERATION
Comparing different design concepts and finalising a form, Choosing one iteration out of the various options.

05 PLAN DEVELOPMENT/ ZONING
Spatial planning and zoning of the finalised iteration.

06 DESIGN DEVELOPMENT
Developing the design further by adding details like structure, services etc.

07 SIMULATIONS
Simulating the form and analysing the results obtained from them

08 DESIGN DETAILING
Detailing the design according to observations from simulations. This included designing shading devices etc.

09 10 CONTESTS
Incorporating the strategies for the 10 contests in the final design.

10 FINAL DESIGN REPORT
Compiling the report explaining various details about the design.

Design process

Our design process involved an integrated design approach where in we looked at multiple paramters and criteria at once to arrive at a holistic design.

Practicality
Looking at practicality and feasibility of design ideas and solutions.

Data driven design decisions
Taking major design decisions based on data and analysing the data.

Design and aesthetics
Designing such that aesthetics are not compromised in order to cater to other criteria and parameters.

Innovation
Coming up with innovative solutions which are cost effective and optimize the overall design

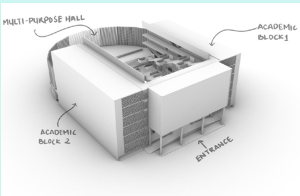
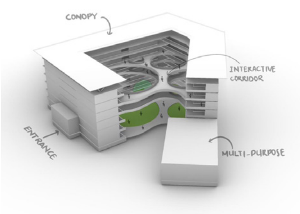
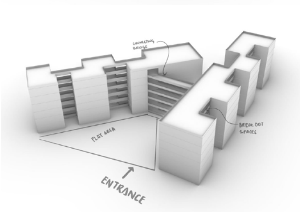
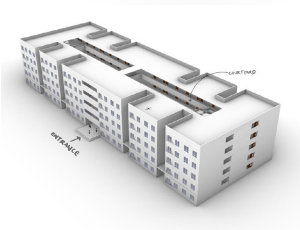
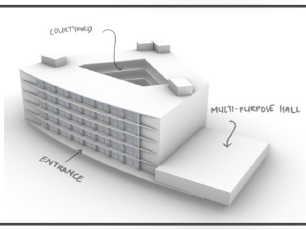
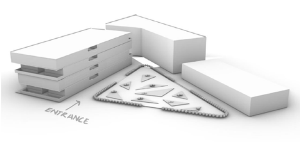
Research and precedent studies.
Researching about already existing materials to gain knowledge

Design documentation

DESIGN ITERATIONS

We created a matrix and tried mapping all the iterations according to few parameters like aesthetics, functionality, passive design etc. This helped in giving a clear idea on how to proceed with the final iteration.

Table 2 Design iterations matrix

S no	Iterations	Aesthetic and Design	Passive design	Fire safety	Structural system	Low Energy usage	Functionality and user experience
1.		✓	✓	✓	✓	✓	✓
2.		✓	✓				✓
3.		✓	✓	✓			
4.			✓	✓	✓	✓	
5.			✓	✓		✓	
6.		✓	✓	✓			

Design documentation

ARCHITECTURAL DESIGN

Design Concept and form development

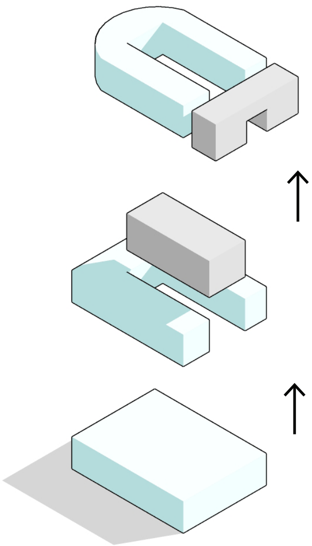


Fig.3 Concept development

3. The subtracted block from the centre was accommodated in the front face of the building to create a semi open space and an entrance was provided. The form follows the traditional architecture of the region.

2. A void was created in the front side, forming a courtyard like element which would aid in passive cooling and natural ventilation.

1. A simple block was created by following the Built up area and ground coverage requirements given by the project partner and the local building codes.

Site plan

The site is planned in such a way that the orientation enables maximum natural light to enter into the activity spaces. The school along with the surrounding proposed buildings, creates a shaded space for the playground, which was a requirement from the project partner's brief. The site has 2 means of access, one for the bus-drop off, and the other for the visitors. There is a separate provision given for parking 2 wheelers and bicycles and the 4 wheelers.

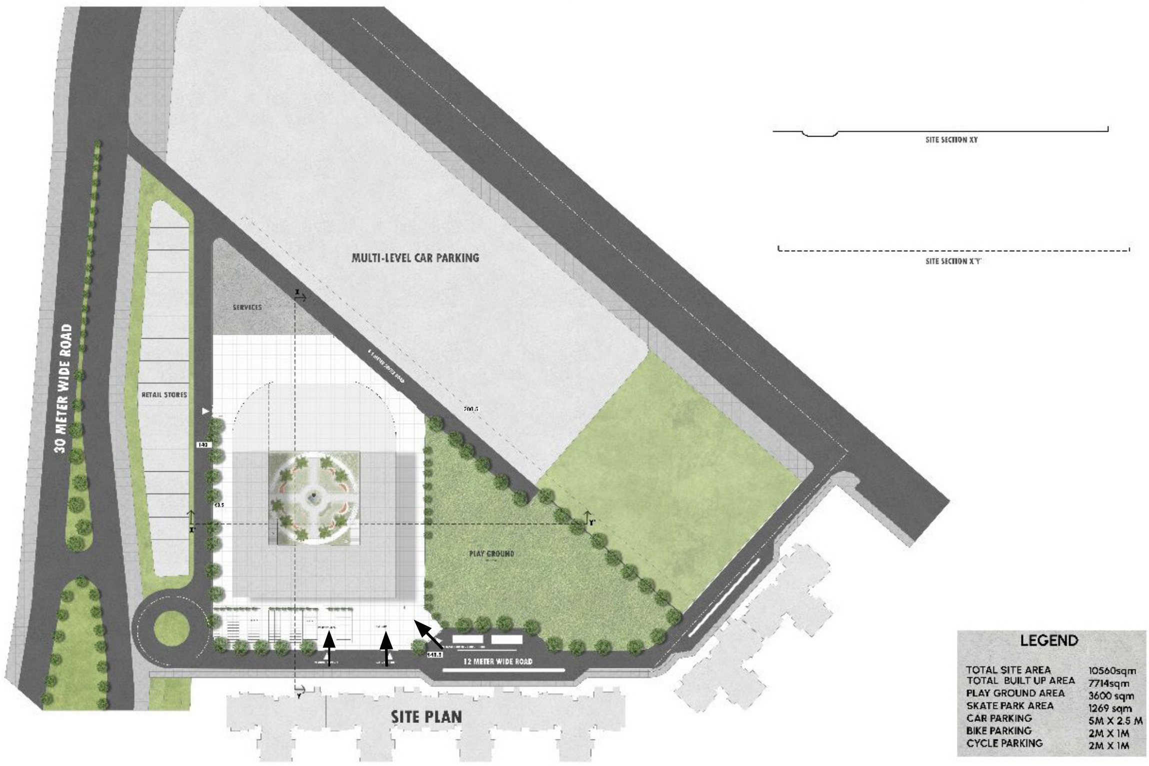


Fig.4 Site plan

Design documentation

ARCHITECTURAL DESIGN

Exterior views and design of spaces

Fig.5Exterior view1

Staircase with scaffolding bamboo posts placed on the courtyard side.

Corridors - singly loaded with classrooms on one side. All spaces face the courtyard in the centre.

Fig.6 Exterior view2

Fig.7 Exterior view3

Double height main entrance space. Simple masonry arches used to emphasize the space.

Planting, landscape and saraswati idol in the centre. Seating areas are integrated with the landscaping.

Fig.8 Exterior view4

Fig.9 Exterior view5

Central courtyard space can be used for informal gatherings and meetings.

yoga room planned on the terrace above 5th floor receives morning sunlight from the east which makes it good for health.

Fig.10 Exterior view6

Fig.11 Section view

Design documentation

ARCHITECTURAL DESIGN

Interiors and spaces

The interiors have been planned keeping in mind the requirements of the project partner as well as the comfort of the users - the children. The aim is to create an environment suitable for learning and leisure at the same time.

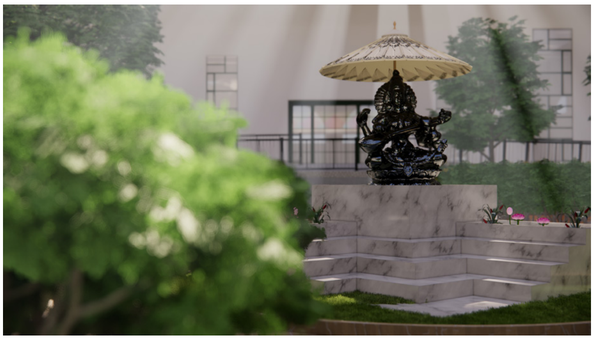


Fig.12 interior view1

Saraswati idol
In the courtyard space in the centre of the building, a saraswati idol is placed as per the requirements of the project partner. The idol is visible directly from the entrance of the school building thus giving a sense of a space related to education and study.

The interiors of the LKG and UKG(kindergarten) classrooms are planned in such a way that the colors are in pastel shades and are comfortable for the children of small ages. A number of cabinets and shelves are provided for storing different items.


Fig.13 interior view2


Fig.14 interior view3

The nursery classrooms are planned in a spacious way. The ceiling and walls have artwork and interesting forms that would help toddlers learn and develop their cognition. Play equipment and a small stepped area is provided for leisure activities.

The higher classes have seating and tables with greater heights based on the anthropometry. Windows on both sides of the classroom ensures good natural ventilation and daylight in the spaces. All classrooms open to the outside providing a view to the outside, thus blurring the boundaries between inside and outside.


Fig.15 interior view4

Design documentation

HEALTH AND WELL BEING

Indoor air quality and thermal comfort was achieved by using natural ventilation strategies along with the air conditioning system.
It was observed that after using the air conditioning system, the operative temperature was following the outside dry bulb temperature and the air temperature.
The radiant temperature which is the temperature felt by the occupants is slightly higher than the operative temperature but is maintained at a constant level..

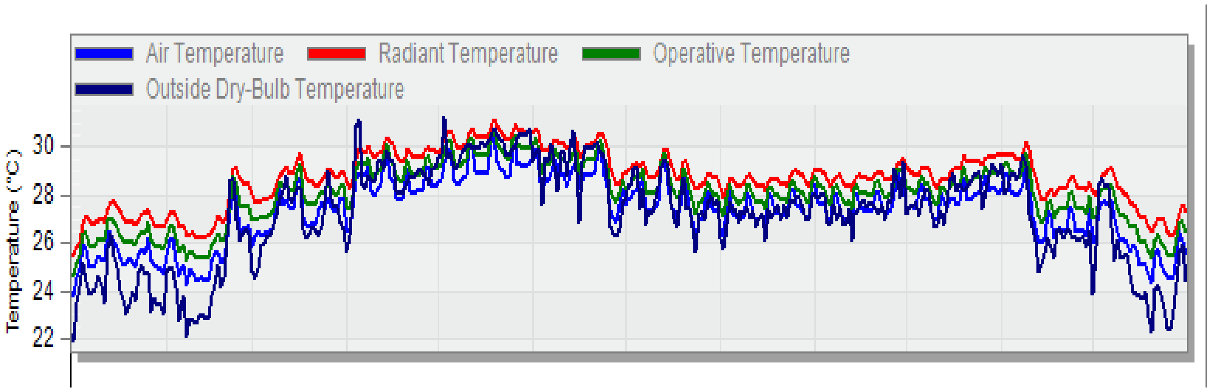


Fig.16 Indoor comfort Temperature graph

With reference to findings from pre-design analysis in Appendix, the thermal comfort temperatures have been achieved by using the mixed mode operation air conditioning system for classrooms.

Each classroom has 2 openings - one opening towards the outside and the other towards the internal corridor. This ensures that there is ample natural ventilation through the openings.

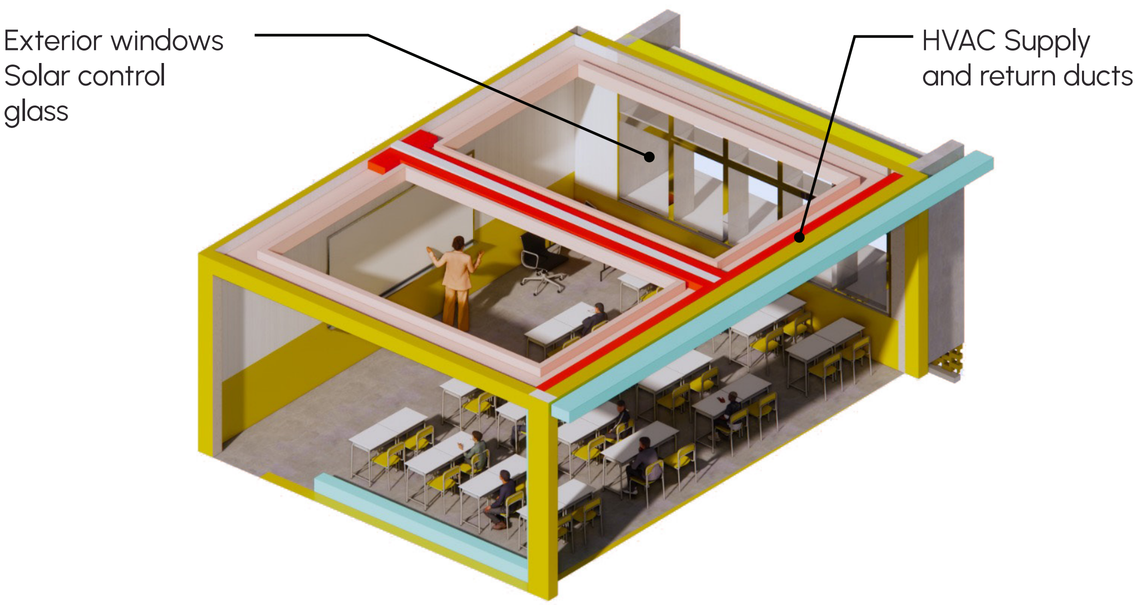


Fig.17 HVAC system classroom detail

Design documentation

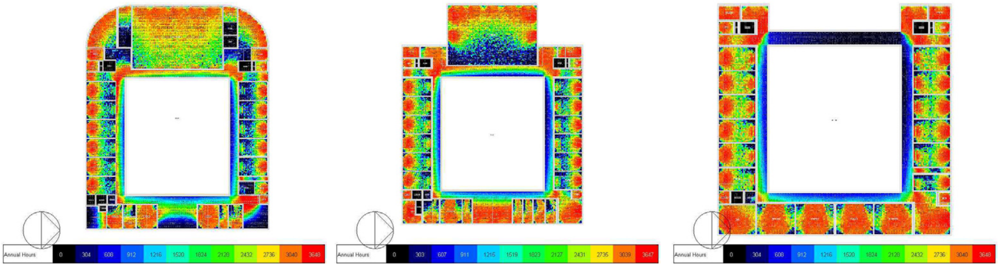
HEALTH AND WELL BEING

Daylighting and Visual Comfort

Spatial Daylight Autonomy(SDA) and Useful Daylight Illuminance(UDI) were analysed using the daylight simulation for each floor of the building. It was observed that the orientation of the building aided in bringing natural light into the spaces, thus making it more healthier. From the maps, it can be concluded that the occupied spaces in the building have a useful daylight of 300 lux or more for the most time of the year. The labs and other activity spaces in the higher floors receive most natural light.

UDI maps

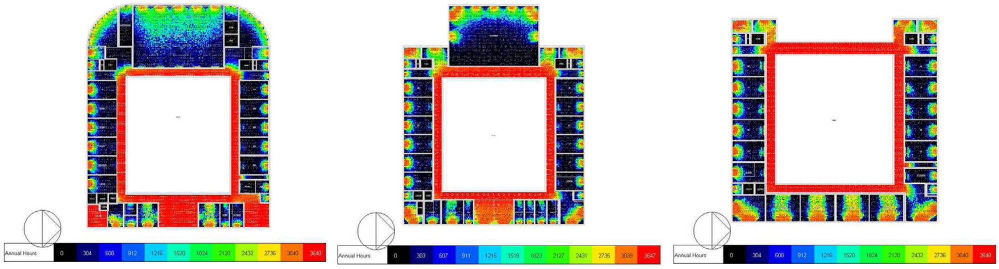
Fig.18 UDI maps ground to second floor



Ground floor | First floor | Second floor

SDA maps

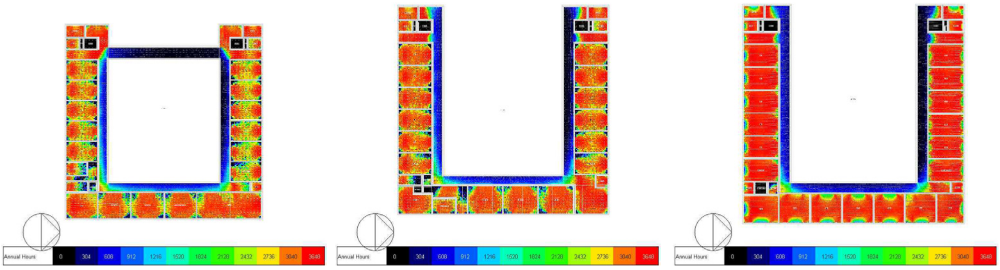
Fig.19 SDA maps ground to second floor



Ground floor | First floor | Second floor

UDI maps

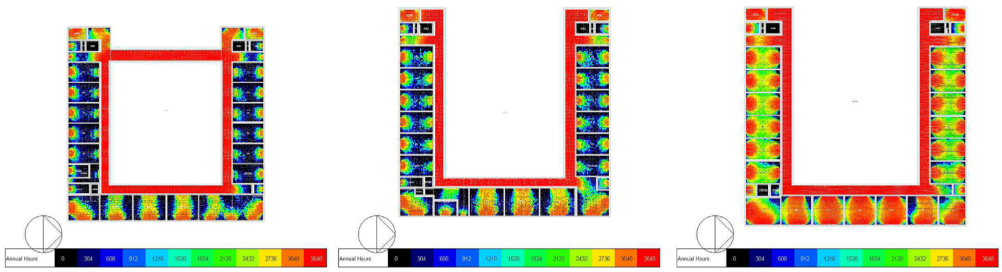
Fig.20 UDI maps third to fifth floor



Third floor | Fourth floor | Fifth floor

SDA maps

Fig.21 SDA maps third to fifth floor



Third floor | Fourth floor | Fifth floor

Design documentation

ENGINEERING AND OPERATIONS

HVAC System

We used an air cooled VRF system with Dedicated Outdoor Air System(DOAS) for the school building. The project partner required the classrooms to be unconditioned. We proposed to use a VRF system so that energy efficiency is achieved and sensible cooling load is reduced due to variable flow of refrigerants to the respective indoor units based on the cooling demand.

The classrooms are conditioned through natural ventilation strategies and the air conditioning system is operated as and when required. The mixed mode operation of air conditioning is used with dehumidification to achieve thermal comfort in the classroom spaces.

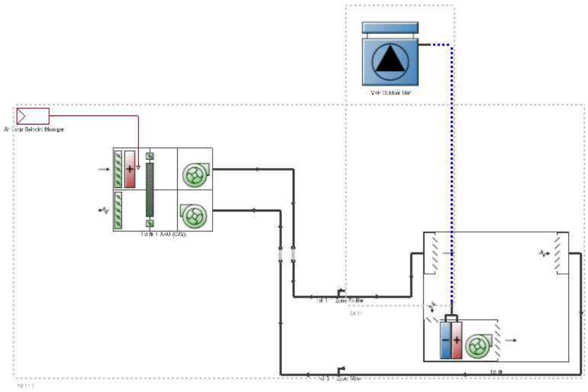


Fig.22 HVAC system layout

In order to size the air conditioning system according to the load and demand, an outdoor unit is planned for each floor of the building to condition the various zones in each floor. The cooling load reduces due to the splitting of outdoor units among the various zones.

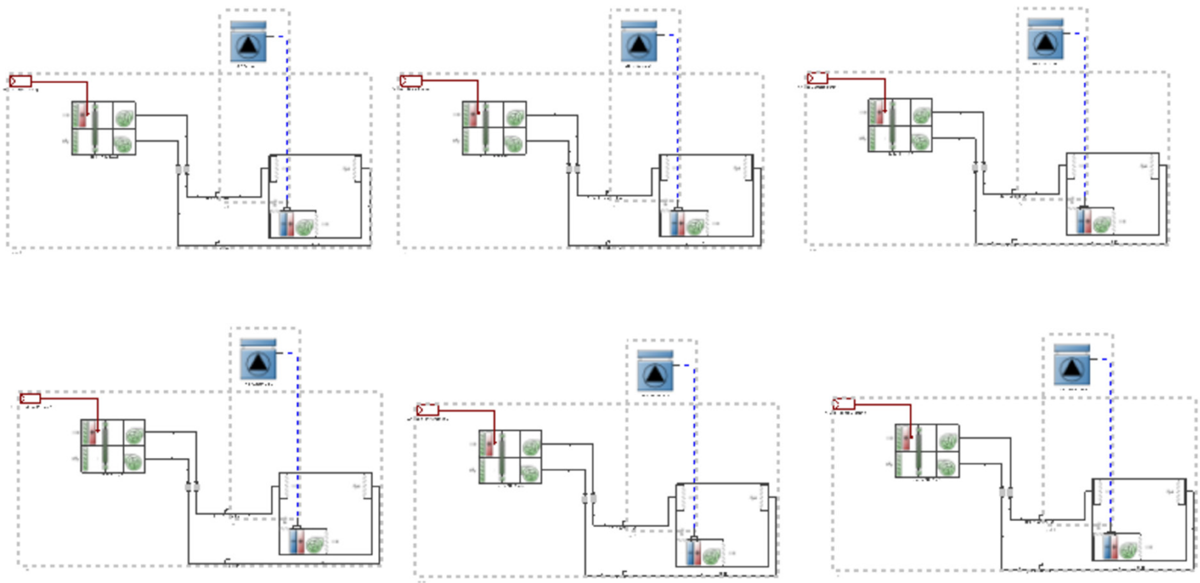


Fig.23 HVAC system zone layout

Design documentation

ENGINEERING AND OPERATIONS

Structural design

The spaces in the building are all column free. the classrooms and activity spaces in the building do not have any column in between them. This ensures that all areas in the building seem spacious without any hindrance of columns of other structural elements.

The structural system is designed as an RCC moment frame structure with fully enclosed circulation systems for fire safety. The structural system is also divided into 3 different parts with a small seismic gap in between them.

Floor to floor height - 3.6m from top of slab to lower part of slab on next floor

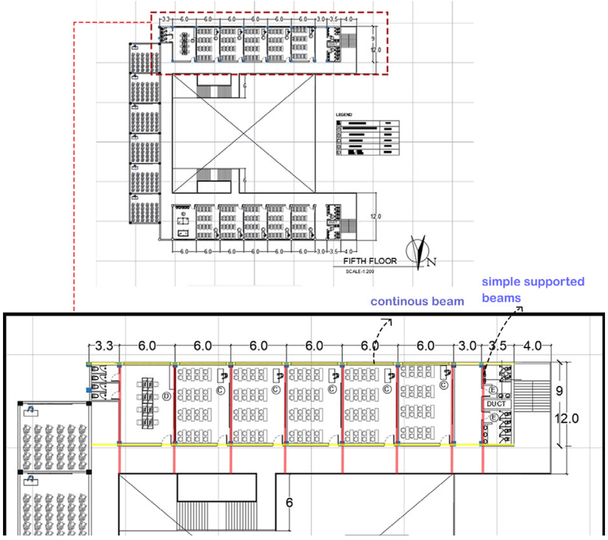


Fig.24 Structural system plan view

Beam size calculation

We have used two types of beams in our structure to achieve strength
Continuous beam with single end and simply supported beam
Whereas continuous beam with single end is used in designing the longer spans of the structure while simply supported beam is used in designing for shorter spans

For simple supported beam	For continuous beam	For g+5 storey building, it requires minimum beam size 400mmx300mm, so we considered depth as 400mm .
Effective depth {d} =9/20 =.45M = 450mm	Effective depth {d} =6/26 =.23M = 230mm	
Total depth {D} =450+8+20 =478 mm =480 mm (say)	Total depth {D} =230+8+20 =258 mm =260 mm say	Total depth {D} =400+8+20 =428 mm, 430mm (say)
Width = Depth/1.5 =480/1.5 =320 mm	Width = Depth/1.5 =260/1.5 =173.33	Width = Depth/1.5 =430/1.5 =286.66 , 290mm (say)

So, provide a beam of 320x 480 for simply supported beam and 290 x 430 for a continuous beam

Column size calculation

Load from slab
Slab thickness: 125mm
Self weight of the slab: 0.125 x 25= 3.125 KN/sqm
Floor finish: 1KN/sqm
Live load: 3 KN/sqm (as per IS 875)
Total load: 7.125KN/sqm
Influence area (C1): 3 x 4.5 = 12.5sqm
Slab load on column: 7.125 x 12.5 x 5 =480.93KN
Similarly, load from the remaining floors is 125.1kN
Total load: 500.4kN

C1
Load from plinth beam: 0.48 x 0.32 x 25 = 3.84KN/m
Self weight of wall on plinth beam: 0.32 x (3.6-0.48) x 24 = 23.96KN/m
Total load: 27.8 COLUMN KN/m
(27.8 x 9) /2 =125.1 kN

Design documentation

ENGINEERING AND OPERATIONS

Structural design

Safe load carrying capacity of the column (IS 456:2000 cl.39.3)
Pu=0.4fck Ac + 0.67 fy Asc
Pu= 1100 x 1.5= 1650 kN
fck= 25n/sqmm
Ac= ?
fy = 550 N/sqmm
Asc= 0.8% to 6% of the gross sectional area of column
(IS 456:2000, CL.26.5.3.1)
Ag= Area of concrete + Area of steel

Consider Asc= 0.8% of the gross area
Ag = Ac + 0.008Ag
Ac = 0.992 Ag

Pu=0.4 x 25 x 0.992Ag + 0.67 x 550 x 0.08 Ag
2100 = 9.92Ag + 2.68 Ag
Ag = 1650/12.6
Minimum width of the column shall not be less than 20db or 300mm (IS-13920,cl.7.1.1)
db - diameter of the largest longitudinal bar in the beam passing through or anchoring into the column
Min. dia for beams- 12mm (longitudinal bar)
20 x 12 = 240mm = b, Area = b x d,
d= 130.95x1000/240 = 545mm

Total load on column
Load from slab: 480.93kN
Load from beam: 500.4kN
Total load on column (C1) = 981.53kN
Consider 10% extra load: 198.133kN
Total load on column (C1)= 1079.46 kN
(say 1100 kN)

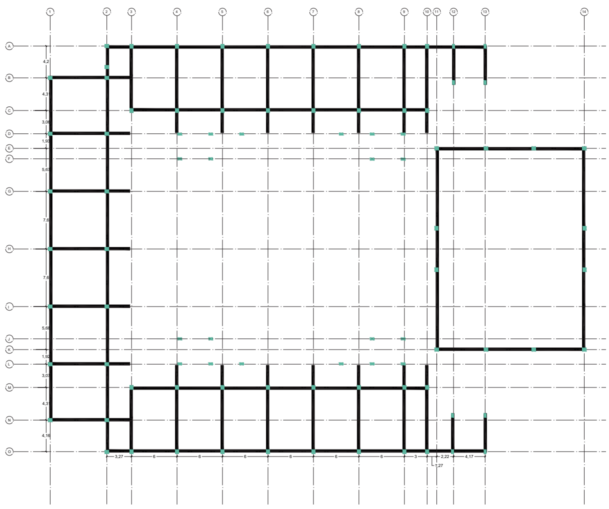
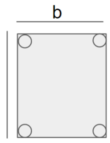
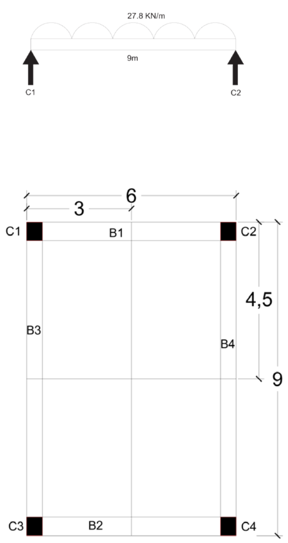


Fig.25 Structural system with grids



Size of the column= 300 x 545 mm
Reinforcement area= 0.8% (300x545)
Reinforcement area= 1308 sq mm
Provide 4 nos of 12mm dia bar.



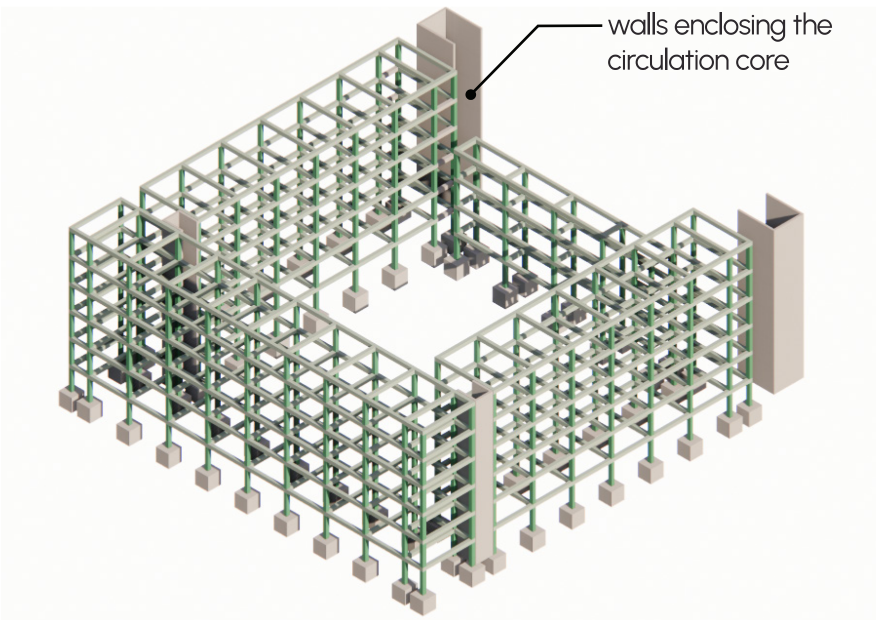


Fig.26 Structural system detail

Fig.27 Structural system detail axonometric view

Design documentation

ENERGY PERFORMANCE

Annual Energy consumption and Energy conservation measures

We used a set of strategies to reduce the energy consumption by simulating the results in Design Builder.

We achieved an EPI of 56.66 as the final energy by reducing loads due to lighting and miscellaneos loads. With lighting controls, the demand on lighting was reduced and spaces were illuminated with natural light.

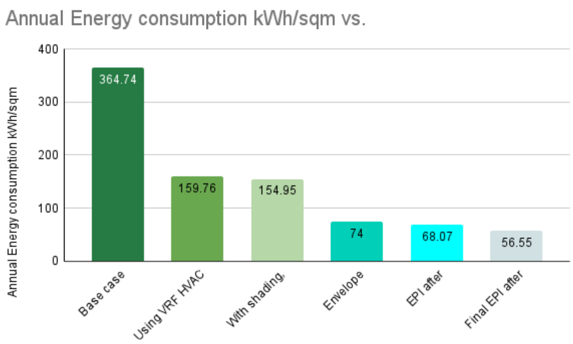


Fig.28 Annual energy consumption per sqm vs strategies

EPI comparison between air conditioning system for classrooms and without air conditioning system for classrooms.
The cooling load reduces significantly when air conditioning for classrooms is not provided, but this compromises on the occupant's thermal comfort.
The Energy consumption is reduced by about 35% when classrooms are not air conditioned.

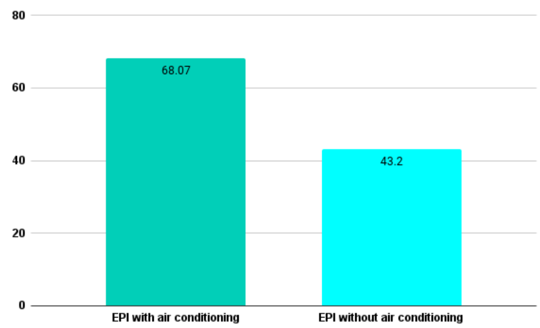


Fig.29 EPI with and without air conditioning

Building areas considered for simulation

Building details	Area [m2]
Total Building Area	10047.24
Net Conditioned Building Area	5713.57
Unconditioned Building Area	4333.67

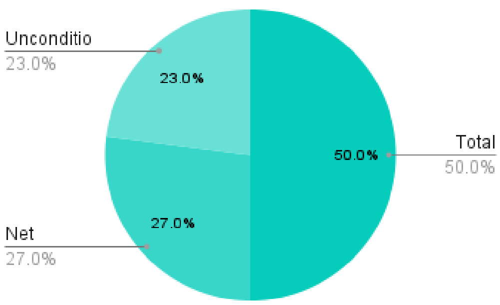


Fig.30 Building areas conditioning

End Uses Annually

Use	Electricity [kWh]
Heating	3261.10
Cooling	261715.31
Interior Lighting	56279.05
Interior Equipment	41332.24
Fans	206440.61
Total End use	569028.31

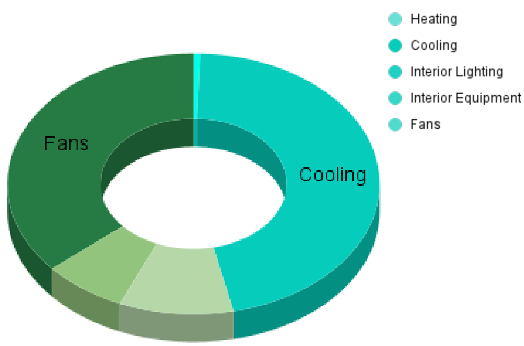


Fig.31 Annual end uses

Design documentation

ENERGY PERFORMANCE

Envelope specifications

Table 3 Exterior walls specifications

Exterior walls

Material	Thickness in mm
Outside layer Cement plaster AAC block wall Cement plaster Inside layer	 30mm 230 mm 30 mm
Total thickness	290 mm
U value and properties	0.427 W/m²-K

Table 4 Floor and slab specifications

Floor and roof slabs

Material	Thickness in mm
Outside layer Cement plaster XPS insulation R.C.C slab Gypsum plasterboard Inside layer	 100 mm 150 mm 30 mm 13 mm
Total thickness	293 mm
U value and properties	0.302 W/m²-K

Table 5 Glazing specifications

Glazing

Brand name/type of glazing	Asahi Solar control glass
U value and properties	1.7 W/m²-K
SHGC	0.44
VLT	0.54

Table 6 Glazing specifications

Interior Glazing

Brand name/type of glazing	Asahi 6mm clear lite glass
U value and properties	1.7 W/m²-K
SHGC	0.44
VLT	0.54

Electricity generation - Solar panels

Area of roof exposed	2000 sqm
Panel dimensions	2108 X 1048 X 35
Weight	24.3 kg
Front cover	3.2 mm tempered glass
Area of one panel	2.2 sqm.
Annual average irradiation on panels	1976.36 kWh/m²

Brand name	Canadian Solar
Model name	HiKu High Power Mono Perc
Peak power in Watts	465 Watts
Panel efficiency	21.1 %
Array tilt angle	20

Table 7 Solar panel specifications

Area of roof exposed to sun = 2396.98 sqm approx.

Total Solar panel area - 2200 sqm

No. of Solar panels - 900 units

Performance ratio = 0.75

Total Solar energy generated on site - **6,01,323 kWh/Year** (more than energy consumption, Net zero achieved.)

Design documentation

WATER PERFORMANCE

Table 8 Water demand

No.	Occupants	No of Occupants	Usage as per NBC	As per NBC		Total Usage(In ltrs)	
				Grey Water	Black Water	Grey water	Black Water
1.	Students	2564	45 LPD	25 LPD	20 LPD	64,100	51,280
2.	Faculty	160				4,000	3,200
3	Staff	25				625	500
4.	Visitors	50	10 LPD	2 LPD	8 LPD	100	400
	Total	2800				68,825	55,380

Table 9 Rainfall potential

Months	Rain fall(mm)	Effective Rain(mm)	Rainfall Potential (ltrs)
January	3.1	0	0
February	0	0	0
March	3.1	0	0
April	3.0	0	0
May	24.8	19.8	50,004
June	468	463	11,69,306
July	678	673	16,99,661
August	409	404	10,20,302
September	270	265	6,69,257
October	86.8	81.8	2,06,585
November	15	10	25,255
December	6.2	1.2	3,030
Annual		1917.8	48,43,400

Table 10 Water requirements

Water Requirements	As per NBC	Reduced Requirements
Domestic Use	25 LPD	12LPD
• Drinking		
• Cleaning	• 6LPM	• 3LPM
Flushing Toilet	20 LPD	8LPD
Total Requirement	45LPD	20LPD

The total water consumed after reduction is 55,480 ltrs
Grey Water - 33,088ltrs
Black Water - 22,392ltrs
With Efficient Conservation Methods and Low water consumption Fixtures ,we can achieve 55.32% reduction in Water Consumption

The Annual harvested rain water is 48,43,400 ltrs.The required capacity for rain water harvesting tank is 1000 cu.m

Table 11 Rainwater harvesting potential

Rainwater harvesting surfaces	Area sq.m	Run off coefficient	Effective catchment area sq.m
Roof surface	2813	0.77	2166
Hard scaped areas	201.7	0.70	141.1
Soft scaped areas	728.3	0.30	218.4
Total Effective Catchment area			2525.5

Table 12 Irrigation water usage

Irrigation Use		
	Base	Proposed
L/m²	1.7	1.0
Area m²	4,046	4,046
Max LPD	6,878.2	4,046

The total water used for Irrigation is 4,046 Liters per day

Annual water consumption

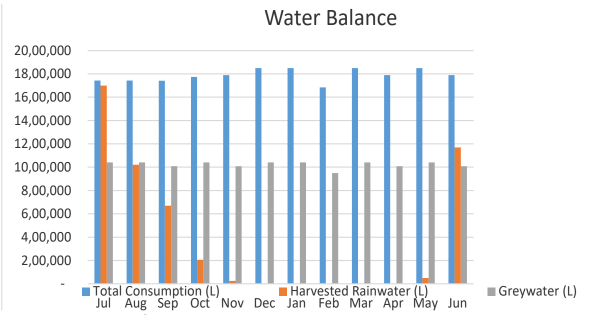


Fig.32 Water Balance

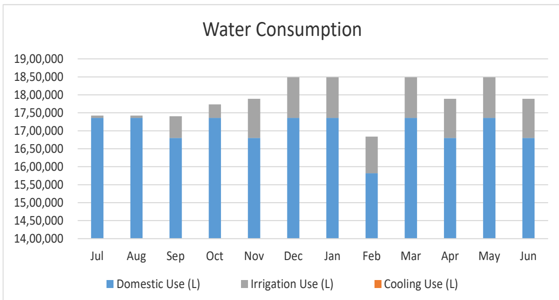


Fig.33 Water Consumption

Design documentation

WATER PERFORMANCE

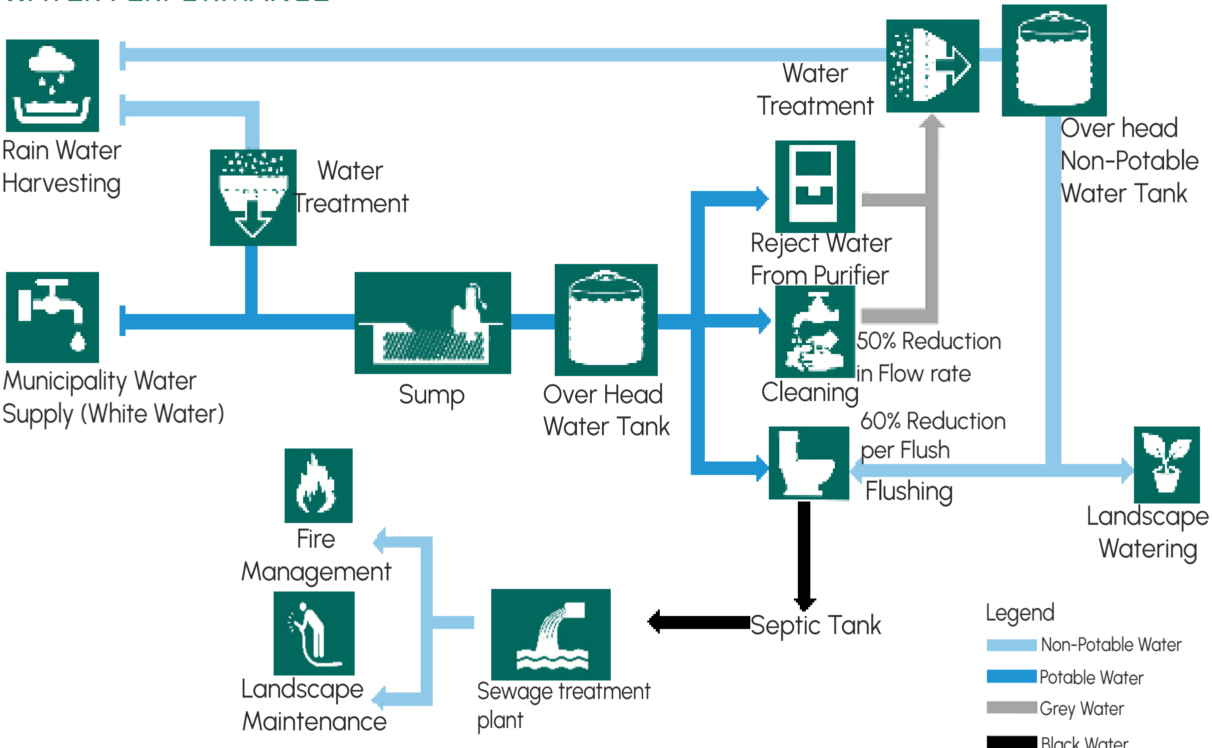


Fig.34 Water Supply flow/ Water cycle

Annual water consumption calculations

Table 13 Water Consumption calculations

		CONSUMPTION				WATER SOURCES				
Month	Days in month	Domestic Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)	Municipal Water (L)	Rain Water	Grey water (L)	Blackwater (L)	Total Stored
Jul	31	17,36,000	5%	6,271	17,42,271	-	1699661	10,41,600	6,94,400	998990
Aug	31	17,36,000	5%	6,271	17,42,271	-	1020302	10,41,600	6,94,400	1318621
Sep	30	16,80,000	50%	60,690	17,40,690	-	669257	10,08,000	6,72,000	1255188
Oct	31	17,36,000	30%	37,627	17,73,627	-	206585	10,41,600	6,94,400	729746
Nov	30	16,80,000	90%	1,09,242	17,89,242	4,10,563	25255	10,08,000	6,72,000	384322
Dec	31	17,36,000	90%	1,12,883	18,48,883	7,86,534	3030	10,41,600	6,94,400	366603
Jan	31	17,36,000	90%	1,12,883	18,48,883	7,02,903	0	10,41,600	6,94,400	262223
Feb	28	15,82,000	90%	1,01,959	16,83,959	6,84,854	0	9,49,200	6,32,800	212318
Mar	31	17,36,000	90%	1,12,883	18,48,883	8,14,986	0	10,41,600	6,94,400	220021
Apr	30	16,80,000	90%	1,09,242	17,89,242	7,96,649	0	10,08,000	6,72,000	235428
May	31	17,36,000	90%	1,12,883	18,48,883	8,18,635	50004	10,41,600	6,94,400	296784
Jun	30	16,80,000	90%	1,09,242	17,89,242	-	1169306	10,08,000	6,72,000	684848
Total				9,92,076	2,14,46,076	50,15,124	48,43,400	1,22,72,400	81,81,600	

The required Over head water tank capacity is 2000 cu.m

Design documentation

WATER PERFORMANCE

Various strategies were used for efficient reduction in water consumption.

By using efficient water fixtures such as Aerator,Pressure reducing valve and Foam flush toilets ,a total reduction of 55.32% can be achieved in daily water consumption.

Water treatment system

We used sewage water treatment plant For on-site wastewater treatment, we used DEWAT Systems and Constructed Wetlands as a cost effective, natural and sustainable treatment system for wastewater. DEWATS is a technical approach to decentralized wastewater treatment. This system uses physical and biological treatment mechanisms such as sedimentation, floatation, aerobic and anaerobic treatment, to treat both, domestic and industrial wastewater

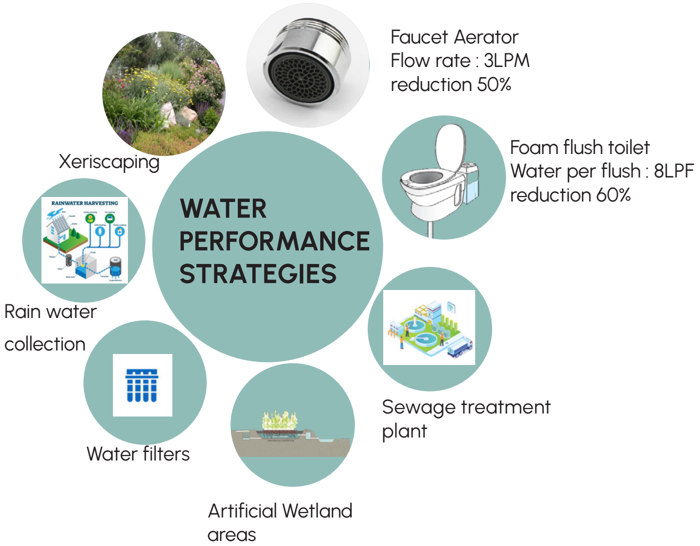


Fig.35 Waterperformance strategies

Irrigation water use

The total water used for Irrigationis 4,046 Liters per day

Irrigation Use		
	Base	Proposed
L/m²	1.7	1.0
Area m²	4,046	4,046
Max LPD	6,878.2	4,046

Table 13 Irrigation water use

Fig.36 Water treatment system in the design

Design documentation

RESILIENCE

Damages due to water flooding

- Dampness due to capillary action causes corrosion in reinforcement
- Salt crystallization creates the plaster or brick to disintegrate over a period of time
- Cracks in buildings shrinks while drying due to the change in water table. Cracks should be filled to avoid penetration of water

High wind effects

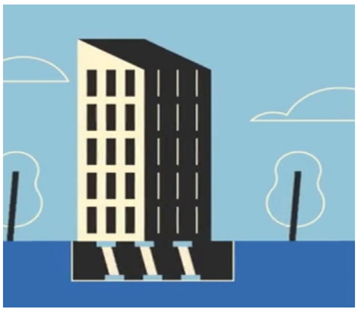
- Thane is under very high damage risk zone as per wind hazard map issued by BMTPC and the avg. Wind velocity noted is 50m/s

Table 14 Disaster types and risks

Disaster type	Description	Damage potential	Damage impact	Design consideration
River floods	Over the past five years, Thane has lost over 60 per cent of its wetlands, including building constructions, slum encroachments and projects like the creekside waterfront	Low	Flooding can occur if there is large amounts of rain and the river overflows.	Yes
Earthquakes	There is a 10% chance of potentially-damaging earth-quake shaking	Medium	In earthquake hazard risk map, thane is under moderate risk zone..	Yes
Coastal floods	Coastal flood hazard is high. Potentially-damaging waves are expected to flood the coast at least once in the next 10 years	High	The probable max-surge height according to the board BMTPC is 5m and the area is not liable to floods.	Yes
Public Health Hazards	The lakes are encroached and experiencing polution due to domestic sewage & solid waste,	Medium	Detoriation of water quality was witnessed.	Yes

Strategies to make the building Earth-quake proof :

Create a flexible foundation- the building is constructed on the top of the flexible pads that isolate the foundation from the ground
Counter forces with damping- tuned dampers attached to beams use pistons and oil to convert the motion into heat and absorb shock
Reinforce the buildings- shear walls and cross braces



Flexible foundation

Shear walls and cross braces, shear walls

Fig.37. Resilience strategies

Strategies to overcome flooding:

Construct permanent barriers- Placing a permanent barrier around the structure can prevent flood waters from reaching building.
Barriers should made of concrete or masonry or by using a level made of compacted layers of soil with an impervious core
Install foundation vents or a sump pump

Design documentation

RESILIENCE

Earthquake and wind resistance

The resilience against wind and earthquake loads was tested using simulations in the Resist software.
It is observed that the structure is safe from both earthquake and wind loads. A combination of moment resisting frames and shear walls ensures that there is less amount of shear, moment or drift forces acting on the building due to earthquakes.

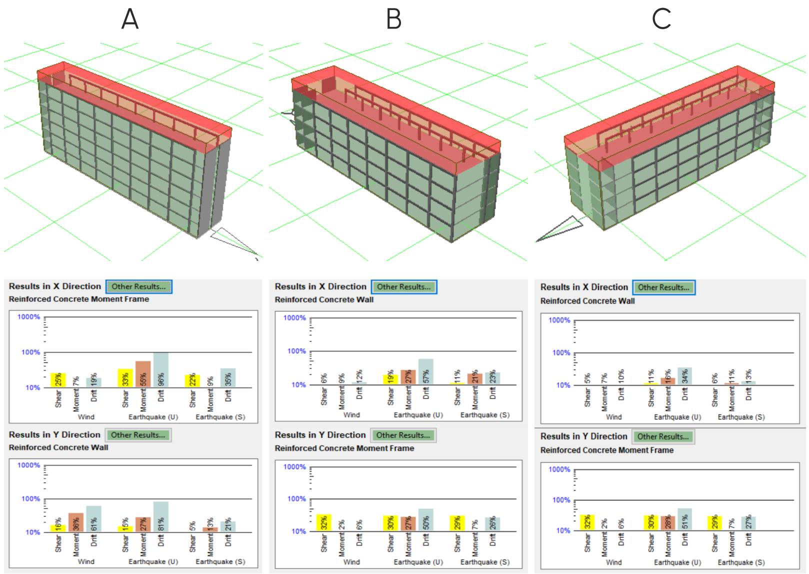


Fig.38. Earthquake and wind resistance simulation

Fire safety

The building is planned such that there are enclosed staircases on both sides ends of the corridor. The central staircase also acts as a refuge and breakput space in case of emergencies.

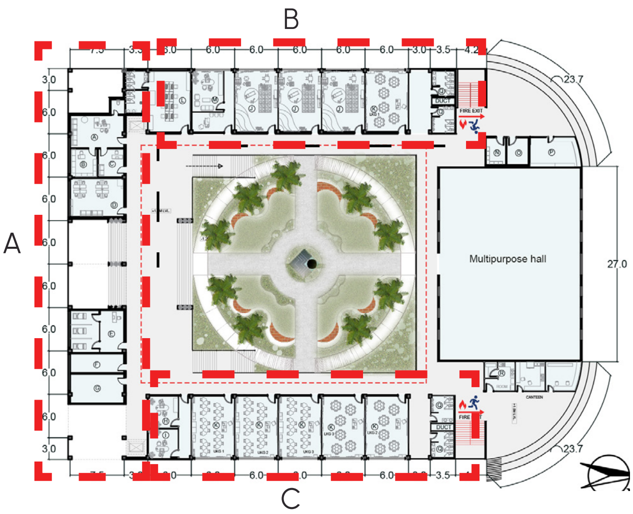


Fig.39. Key plan showing structural system and fire exits

Flood protection.

The building is raised from the ground level by 0.8m to prevent flooding and water from entering inside the building.

Power backup

A service yard is placed on the site to accommodate the STP, Generator, inverter and backup for power.
The inverter stores extra energy from the rooftop PV panels for future usage. The system can also be used to interact with the grid and provide energy to the electricity grid during times of excess storage of energy.

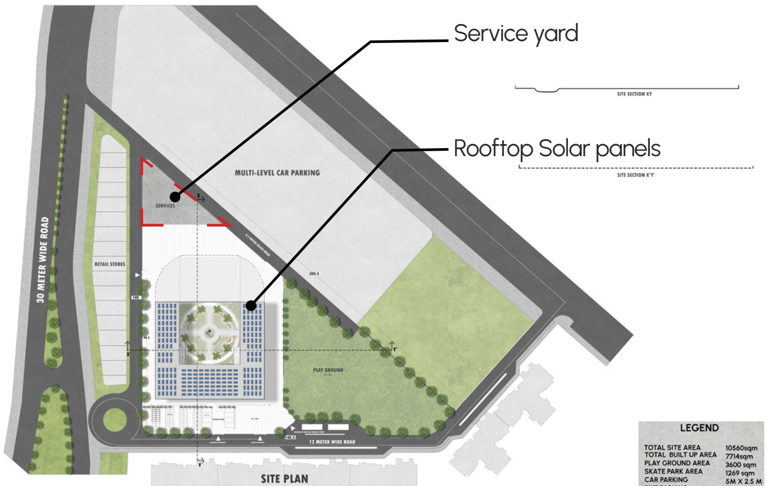


Fig.40. Site plan with service yard

Design documentation

AFFORDABILITY

The cost estimate for the proposed case design is a bit higher than the base case due to higher capital costs. The operational costs reduces significantly due to the energy savings from solar panel installation.

Table 15 Cost estimate project summary

Project Summary

Projec Project Information

Team:	Yuktha		
Division:	Education building	**Land Cost:**	100 Million INR
Site Area (sqm)	10,948	**City:**	DOMBIVILLI
Built-up Area (BUA) (sqm)	10,047	**State:**	MAHARASHTRA
Ground Coverage (Plinth Area) (sqm)	2,921		

S.No.	Particulars	Definition	Baseline Estimate (Project Partner / SOR basis)			Proposed Design Estimate		
			Amount (Million INR)	%	Amount (INR per sqm)	Amount (Million INR)	%	Amount (INR per sqm)
1	Land	Cost of land purchased or leased by the Project Partner	100.00	31.6%	9,953	100.00	38.2%	9,953
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	85.30	27.0%	8,489	103.30	39.4%	10,281
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	14.55	4.6%	1,448	9.20	3.5%	916
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	59.51	18.8%	5,923	0.00	0.0%	-
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	6.59	2.1%	656	6.59	2.5%	656
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	1.88	0.6%	188	3.00	1.1%	299
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	8.39	2.7%	835	8.30	3.2%	826
	TOTAL HARD COST		**276.2**	**87%**	**27,492**	**230.4**	**88%**	**22,931**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	10.00	3.2%	995	10.00	3.2%	995
9	Consultants	Consultant fees on a typical Project	10.00	3.2%	995	10.00	3.2%	995
10	Interest During Construction	Interest paid on loans related to the project during construction	20.25	6.4%	2,016	11.72	3.7%	1,167
	TOTAL SOFT COST		**40.3**	**13%**	**4,006**	**31.7**	**10%**	**3,157**
	TOTAL PROJECT COST		**316.5**	**100%**	**31,498**	**262.1**	**100%**	**26,088**

Capital Expenditure - Annual

Particulars	Baseline Estimate (Project Partner / SOR basis)						Proposed Design Estimate					
	TOTAL (Millons)	YEAR 1	2	3	4	5	TOTAL (Millons)	YEAR 1	2	3	4	5
Land	100.0	100.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0
Civil Works	85.3	57.1	25.6	3.4	0.0	0.0	103.3	67.1	36.2	0.0	0.0	0.0
Internal Works	14.6	0.0	10.2	4.4	0.0	0.0	9.2	1.8	7.4	0.0	0.0	0.0
MEP Services	59.5	0.0	17.9	41.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Equipment & Furnishing	6.6	0.0	0.0	6.6	0.0	0.0	6.6	0.0	6.6	0.0	0.0	0.0
Landscape & Site Development	1.9	0.1	0.4	1.4	0.0	0.0	3.0	0.2	2.9	0.0	0.0	0.0
Contingency	8.4	0.0	0.0	8.4	0.0	0.0	8.3	0.0	8.3	0.0	0.0	0.0
TOTAL HARD COST	**276.2**	**157.2**	**54.0**	**65.8**	**0.0**	**0.0**	**230.4**	**169.1**	**61.3**	**0.0**	**0.0**	**0.0**
Pre Operative Expenses	10.0	6.0	20.0	20.0	0.0	0.0	10.0	6.0	4.0	0.0	0.0	0.0
Consultants	10.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0
Interest During Construction	20.3	5.4	6.7	8.2	0.0	0.0	11.7	5.7	6.0	0.0	0.0	0.0
TOTAL SOFT COST	**40.3**	**11.4**	**26.7**	**28.2**	**0.0**	**0.0**	**31.7**	**11.7**	**10.0**	**0.0**	**0.0**	**0.0**
TOTAL PROJECT COST	**316.5**	**168.6**	**80.7**	**94.0**	**0.0**	**0.0**	**262.1**	**180.8**	**71.3**	**0.0**	**0.0**	**0.0**
Upfront Equity	126.6	67.4	32.3	37.6	0.0	0.0	104.8	72.3	28.5	0.0	0.0	0.0
Debt Drawal Required	**206.0**	101.2	48.4	56.4	0.0	0.0	**151.3**	108.5	42.8	0.0	0.0	0.0

Table 16

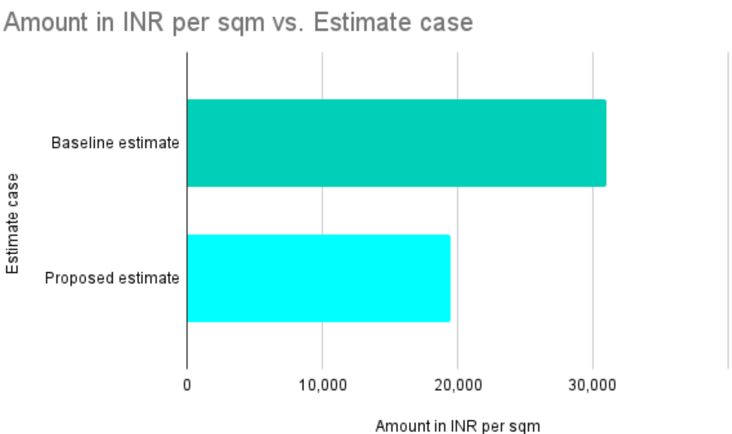


Fig.41. Cost estimate comparison

Design documentation

AFFORDABILITY

The distribution of construction costs for the project is shown in the figure. Civil works accounts for the most cost. In the proposed case design, we have proposed low cost materials for walls which had reduced the overall cost of the civil works.

MEP services includes the HVAC system costs. The use of VRF system with rightsizing reduced the overall cost compared to the base case value.

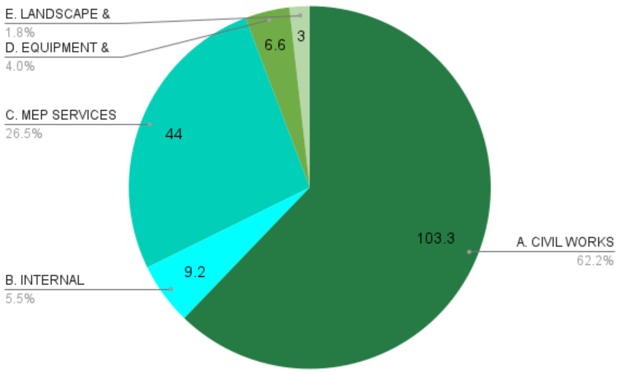


Fig.42. Cost estimate distribution for proposed case in Million INR

Renewable energy Cost estimate

Size of Power plant:-
Feasible plant size as per capacity:- 418 kW

Cost of the plant:-
MNRE current benchmark cost(without GST) Rs. 35886/ kW

Total Electricity generation from Solar Power plant:-
Annual: 6,01,323 kWh
Life-time (25 years): 1,50,33,075 kWh

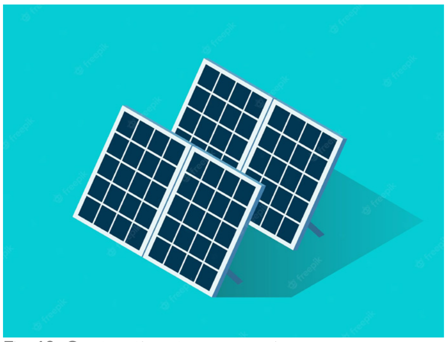


Fig.43. Cost estimate comparison

Savings -
Tariff @ Rs. 8/kWh (for top slab of tariff) - NO increase assumed over 25 years :-

Monthly :	Rs. 4,18,000
Annually :	Rs. 50,16,000
Life-time (25 years) :	Rs. 12,54,00,000

Therefore, the total savings by installing a Solar PV system is about 8-9 times that of the cost of installing the system or capital cost. The savings in operation of the building after the loan amount repaid is significant.

EMI calculation

Cost of Solar PV power plant -	Rs. 1,50,00,348 / kW
Loan interest rate -	8.45 %
Loan Period -	10 years

EMI for loan amount of 15000348 for a period of 10 years @ 8.45 % interest is Rs. 185582 / month

Design documentation

INNOVATION

Organic farming

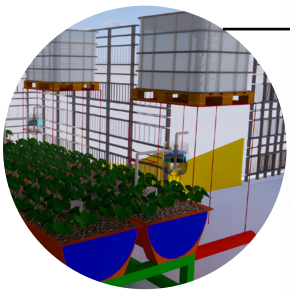
Idea
The idea of an organic farming area is proposed for the school which would improve the pedagogy and learning methodology of the school. Based on precedents, and case studies of similar designs in schools, we wish to propose a unique system of growing plants in the building.
Learning and meditative spaces are integrated with these spaces where plants are grown.

Problem
The learning pedagogy in schools is not practical since it does not encourage learning in a natural setting. There is lesser connect with real world and nature in the traditional education system.

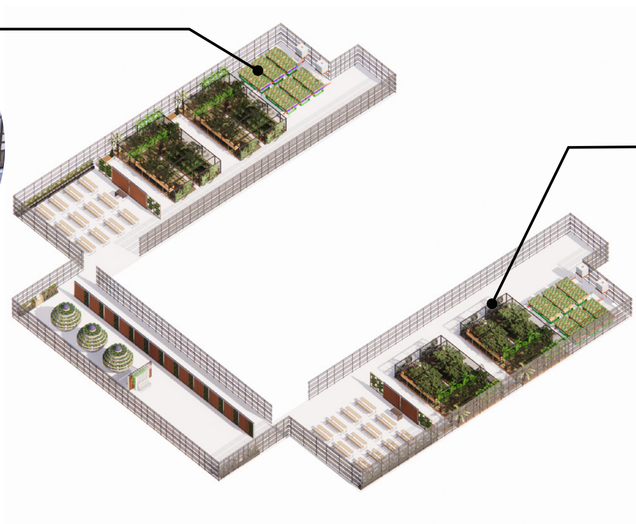
Technology/Solution
The water supply for this is obtained from water tanks placed in the same floor. Recycled grey water from the building can be stored in the tanks and can in turn be used to supply water to these plants. This kind of system thus makes the building self sufficient in water usage and also encourages new methods of learning for students. The concept can be further replicated to other buildings.

Market
This rooftop organic farming system is in the stage of practical application. A company, 'The Living Greens' from Jaipur has found a way to install such systems in the rooftop and for schools specifically.
The system can be scaled up and installed in existing schools and universities.
Approx. cost of installing the system - display space (rooftop or ground) - Rs. 800-1000 sqr ft, storage space (covered) - Rs. 300 sqr ft, Office space - Rs. 200 sqr ft
The ROI(Return Over Investment) would be around 8-9 months.

Benefits and impact
- Using this system would enable the use of treated water from the building and for growing organic items.
- It would also generate awareness and knowledge about nature, cultivation for youngsters.



A water tank is placed beside the pots to supply water to the plants. Natural light is received from the central courtyard space and the southern facade.



Sixth floor terrace view

Small shrubs are grown in this area. Vegetables and Organic items that require less light are planted here.

Fig.44. Innovation - organic farming

Design documentation

INNOVATION

Modular rainwater harvesting system

Idea
We proposed Modular Rainwater Harvesting Tanks, using modern technology to store rainwater for reuse.

Problem
The storage of rainwater for later use is a challenge due to easy contamination from outside matter. There should be some method of storing fresh rainwater and ensuring that it does not get contaminated with foreign materials.

Technology/Solution
These modular tanks are built out of high-quality, recycled polypropylene.
Recycled building materials, minimum maintenance and the modular system make this a very eco-friendly and sustainable solution. A geotextile membrane or sheet is used to cover these modules so that the wate held is not contaminated by other materials. The rooftop rainwater can be redirected to this tank or the tank can be covered by a planter bed to gather direct rainwater.

Market
This system is in the stage of practical application. A company, 'The rainwater project' from Hyderabad, founded by Mrs. Kalpana Ramesh has found a way to install such systems in existing buildings and sites. The system can be scaled up and installed in existing any building typology.
Depending on the scale of the project, type of building and location, the monetary savings varies from 50,000 to 10 lakhs, annually

THE RAINWATER PROJECT

Benefits and impact

- By using this, rainwater storage tanks can be moved and relocated to different areas as necessary.

- The problem of water contamination will be solved.

- There is large monetary savings by installing such a system as it is easy to maintain.

- It is an eco-friendly and sustainable solution due to the use of recycled materials.

- Excess water has a chance to enter the underground aquifers, passing through the tank.

- Dependancy on tankers for providing fresh water is reduced.

Fig.45. Modular rainwater harvesting system

Design documentation

INNOVATION

Facade detail

Idea

To create a facade for shading and ventilation, we developed a detail that would not only look aesthetically pleasing, provide shading from harsh sunlight and provide ventilation but also to be executable on site. Keeping in mind the practicality and construction techniques, the simple facade detail would prove to be effective in serving different functions.

Technology/Solution

The vertical fins block the low angle sun during winters when the radiation is the highest. The horizontal projections block the high angle sun during the afternoon times.

Earth Blocks - Hollow Interlocking Type

Earth Blocks are high-quality building materials made from compressing the right mix of soil with 6-9% cement, based on the mix design

Embodied energy and carbon emissions of Earth Blocks is lesser by 10 and 12 times, when compared with country fired bricks.

The brick jali acts as a skin to the external wall of the building, creates cavity space and helps in reducing the heat gain.

The fenestration design helps in gaining a good amount of sun light at the same time reducing the heat gain.

Double galzed windows helps in increasing the insulation by 40%.

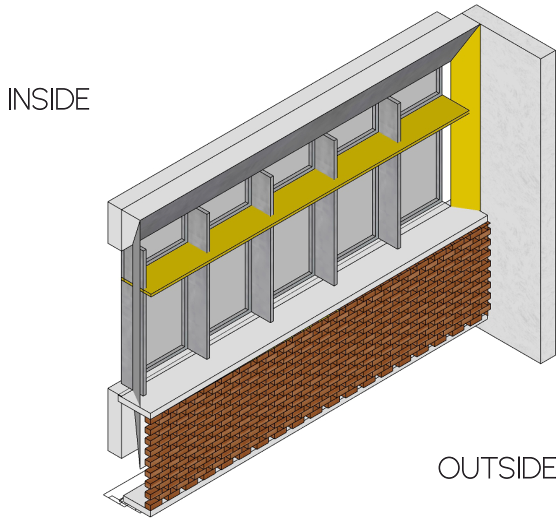


Fig.46. Facade detail view

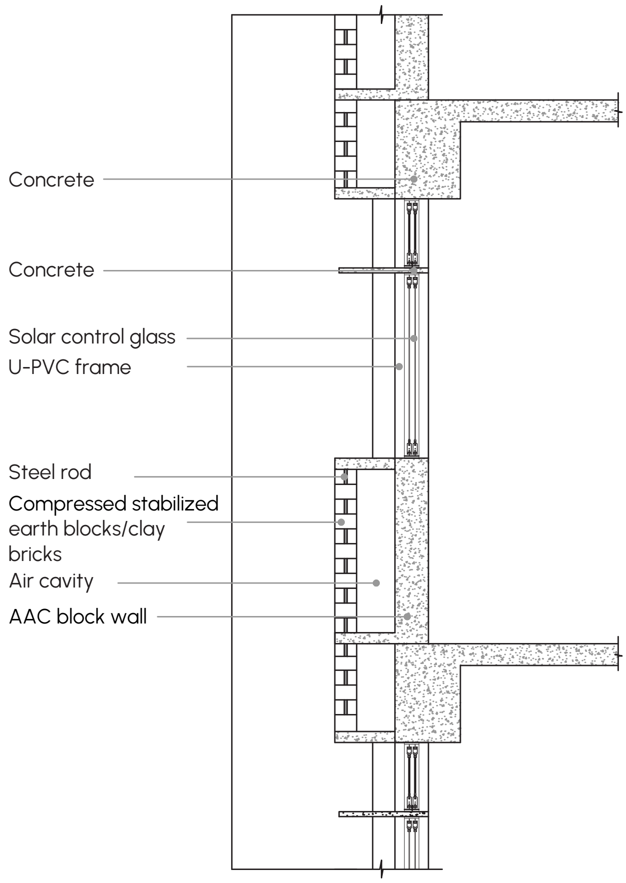


Fig.47. Facade section detail

Design documentation

INNOVATION

Facade detail

Problem
Heat gains from solar radiation is a problem to consider in the design. Solar radiation on facades has a significant impact on the cooling load of the HVAC system. Higher radiation and heat gain increases the load on the air conditioning system.

Market
This technology or solution can be scaled up and used for various educational institutions across India. The product or solution would benefit architects, designers, builders and everyone involved with the construction industry.

Benefits/impacts
- The solution uses low cost materials like clay which can be easily sourced and is abundantly available.
- It reduces the heat gain in the building by acting as a cover to the exterior walls of the building.
- Reduced cooling loads, and long term savings in electricity costs due to use of air conditioning systems.

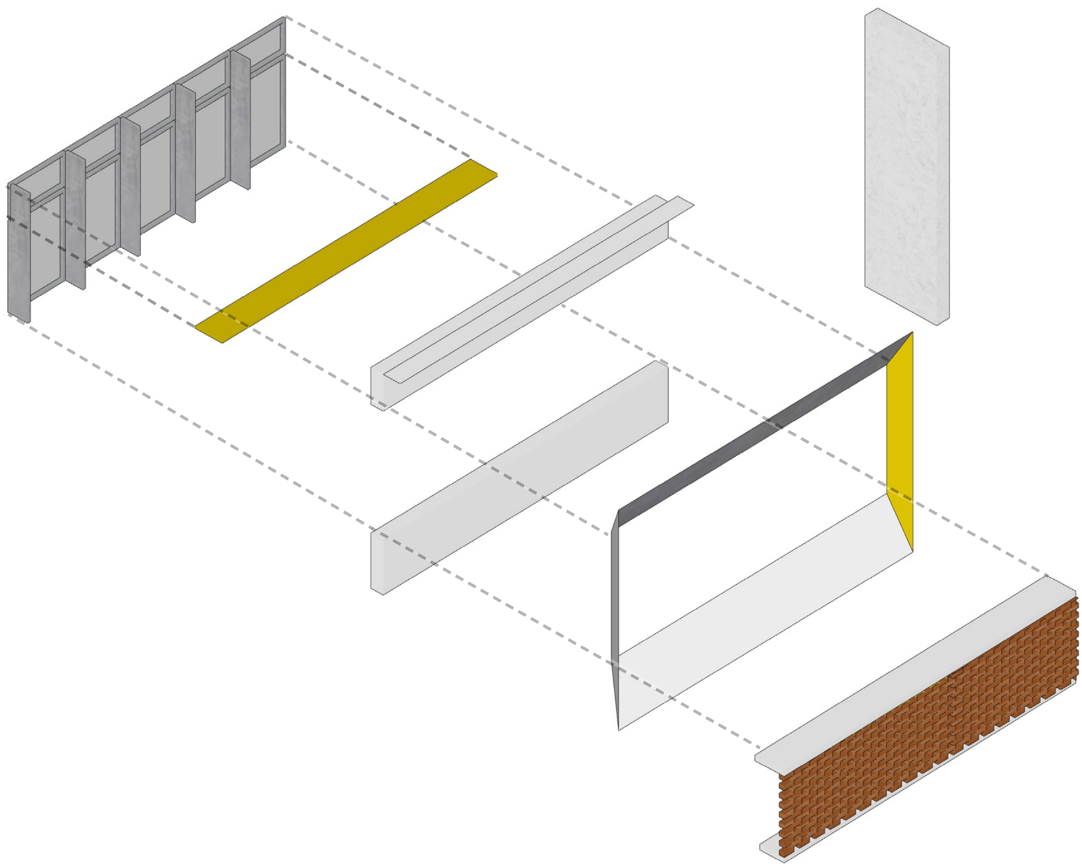


Fig.48. Facade detail exploded view

Design documentation

EMBODIED CARBON

The materials used in the proposed design have lower carbon emissions when compared to the baseline case. By using basic materials like AAC blocks for the wall assembly, the carbon emissions reduces to a great extent compared to the baseline case which is regular brick walls. The solar control glazing also has a low embodied carbon compared to the base case which has aluminium framing.
There is approximately a 62.5% reduction in carbon emissions in the proposed case when compared with the base case value.

System Type	Baseline			
	Material emissions *(kg -CO_2 e)*	Transport 1 *(kg -CO_2 e)*	Transport 2 *(kg -CO_2 e)*	Total *(kg -CO_2 e)*
Wall	212.6	0.2	0.2	213.0
Roof	511.4	1.8	1.2	514.4
Floor	54.9	0.1	0.1	55.2
Fenestration	33.2	0.0	0.0	33.2
Structural	81.7	0.3	0.2	82.2
	Grand Total emissions per functional unit *(kg -CO_2 e)*			898.0

Proposed			
Material emissions *(kg -CO_2 e)*	Transport 1 *(kg -CO_2 e)*	Transport 2 *(kg -CO_2 e)*	Total *(kg -CO_2 e)*
13.2	0.0	0.0	13.3
165.7	0.1	0.1	165.8
45.3	0.0	0.0	45.4
31.2	0.0	0.0	31.3
80.4	0.3	0.2	80.9
Grand Total emissions per functional unit *(kg -CO_2 e)*			336.7

Table 17 Baseline and proposed carbon emissions

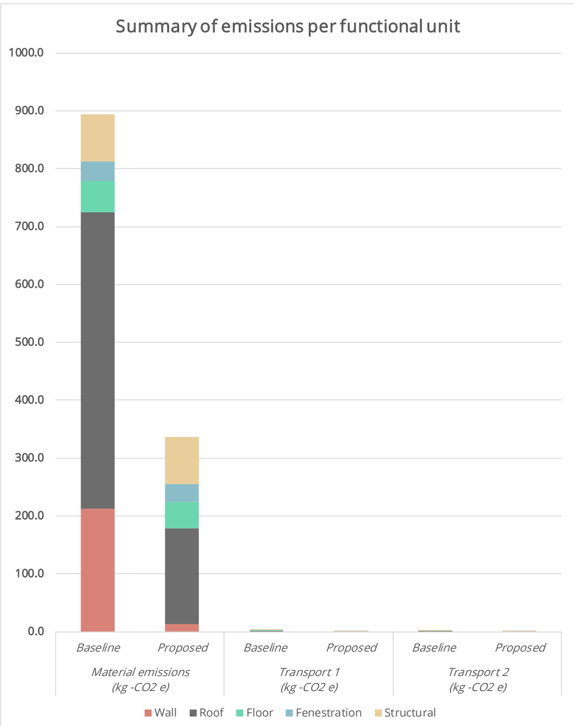


Fig.49. Embodied carbon graph

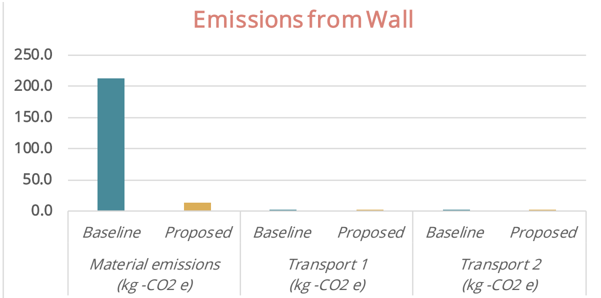


Fig.50. Emissions from wall

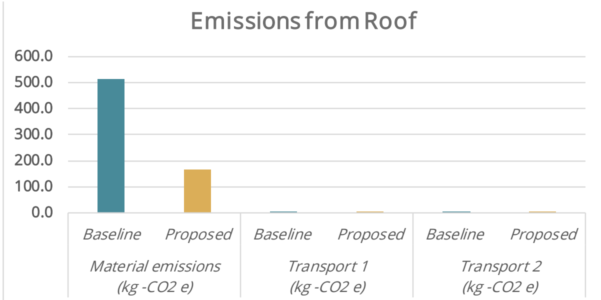


Fig.51. Emissions from roof

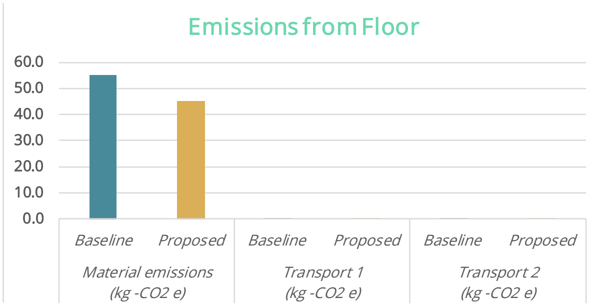


Fig.52. Emissions from floor

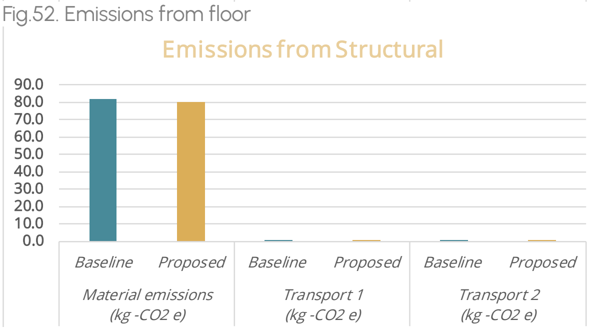


Fig.53. Emissions from structural system

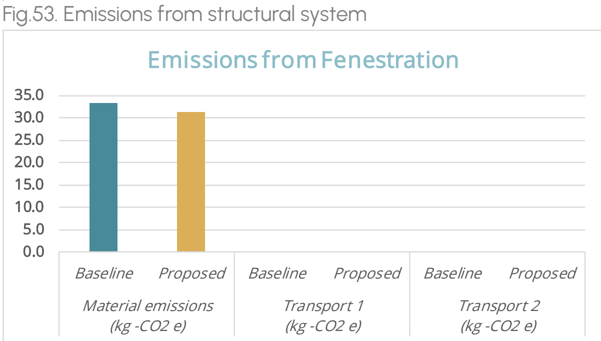


Fig.54. Emissions from fenestration

Design documentation

EMBODIED CARBON

Base case | Proposed case

Table 1 Wall system mass quantities

System type - Wall			
Material	Quantity	Material	Quantity
Brick (common/facing)	3287364.3 kg	AAC(Autoclaved aerated concrete	27429 kg
Cement (ordinary portland)	661095.3 kg	Cement (ordinary portland)	108673.2 kg
M Sand	4437489 kg	M Sand	724488 kg
Paint	1811.45 litres	Paint	974.67 litres
Stone (crushed)	90561 kg		

Table 1 Roof system mass quantities

System type - Roof			
Material	Quantity	Material	Quantity
Cement floor screed(concrete screed)	74427.01 kg	Cement floor screed(concrete screed)	74313.92 kg
Cement (ordinary portland cement)	476584.04 kg	Cement (ordinary portland)	475953.7 kg
Steel reinforcement(steel rebar	11806.27 kg	Steel reinforcement(steel rebar	11806 kg
Water	238033.23 litres	Water	238033.23 litres
Plasterboard	2349049 kg	Plasterboard	2349.49 kg
Cement mortar	54955 kg	Cement mortar	54948.5 kg
Aggregate (mixed gravel)	83149.4 kg	Aggregate (mixed gravel)	83149.4 kg
Expanded Polystyrene insulation (EPS)	1907.7 kg		

Table 1 Floor system mass quantities

System type - Floor			
Material	Quantity	Material	Quantity
Glazed ceramic floor tiles	217581.66 kg	Cement floor screed(concrete screed)	74313.92 kg
Cement (ordinary portland cement)	283473.23 kg	Cement (ordinary portland)	283485.17 kg
Steel reinforcement(steel rebar	44967.83 kg	Steel reinforcement(steel rebar	45182.68 kg
Cement mortar	209320.88 kg	Plasterboard	8983.78 kg
Expanded Polystyrene insulation (EPS)	7266.52 kg	Expanded Polystyrene insulation (EPS)	7266.52 kg
Tile adhesive for ceramic/ concrete tiles	91633.97 kg	Pulverized fuel ash(PFA)	118498.36 kg
Aggregate (mixed gravel)	316700.21 kg	Aggregate (mixed gravel)	316712.5 kg

Design documentation

EMBODIED CARBON

Base case | Proposed case

Table 1 Fenestration system mass quantities

System type - Fenestration - Doors and windows			
Material	Quantity	Material	Quantity
Aluminium extruded profile	2154.36 kg	U-PVC window frame	67.09 kg
glass	19.26 kg	glass	19.26 kg
Gypsum panel	523.05 kg	Partcile board/chipboard	2606.39 kg
		Brick (common/facing)	69576.34 kg
		Cement (ordinary portland)	31668.82 kg

Table 1 Structural system mass quantities

System type - Structural - Beams and Columns			
Material	Quantity	Material	Quantity
Aggregate (mixed gravel)	50099 kg	Aggregate (mixed gravel)	48266.26 kg
Water	143419.37 litres	Water	143419.37 litres
Cement (ordinary portland cement)	129679.31 kg	Cement (ordinary portland)	128396.39 kg
Steel reinforcement(steel rebar	7113.6 kg	Steel reinforcement(steel rebar	6650.38 kg
Sand	906787.5 kg	Sand	914533.04 kg

Design documentation

VALUE PROPOSITION

In order to convey the value of our project to the project partner, we would like to showcase some of the unique selling points of our project.

Qualitative aspects

- The innovative pedagogical methods and technologies utilised in the design proposal which have long term benefits and increase the market value.
- Design features that are unique to or specific to our design proposal, like the intractive staircase, seating in courtyard etc.
- Target users have been identified and the experience of the users have been kept in mind while designing.
- Low embodied carbon values compared to the base case values. This means that the project emits lesser carbon than a similar project elsewhere.
- Landscape integrated with the built structure such that it creates a biophilic design and promotes health and well being.
- Large amounts of daylight is received in activity spaces, thus reducing the need for artificial lighting.

Fig.55. Qualitative value proposition

Quantitative aspects

- Recycled water is used for organic farming and other purposes, thus utilising 5-10 % of the treated water.
- Proposed case has approx. 60% reduction in embodied carbon values, making the project low carbon and sustainable.
- Ventilation rates of 160-200 litres per second in all the classrooms ensures that the indoor air quality is good and there is less concentration of CO_2 in the spaces(less than 1000ppm)
- Thermal comfort is maintained at 22^0 C to 28^0 C in the classrooms and activity spaces.
- The ROI for Solar PV system is 25 years with total savings of Rs. 12,54,00,000. The loan amount for solar panels is repayed within 10 years.

Fig.56. Quantitative value proposition

Appendix

PROJECT PARTNER DETAILS

Our project partner was assigned to us by the Solar Decathalon India Organizers.
The details are as follows:

Organization name: Lodha Group

Project name : Lodha Codename

Project location : Dombivili, Thane district, Mumbai, Maharashtra, India.

Key Individuals

Mrs. Sonal Bhide, Head of Architecture, Township projects, Lodha Group

INDUSTRY PARTNER DETAILS

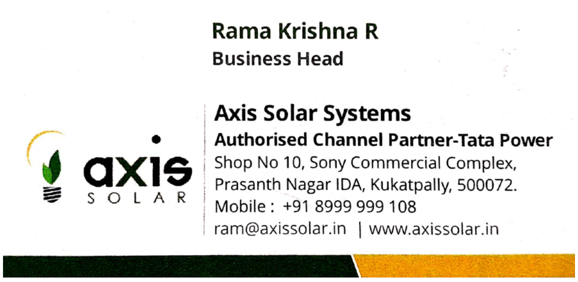
We have contacted professionals from various industries for helping us with our project. Although we could'nt get a confirmation letter from them for the same, their insights were useful in the completion of our project. We have listed out the details below.

Organization name : Axis Solar

Key Individual : Rama Krishna R

Designation : Business Head

Industry : Solar panel suppliers.

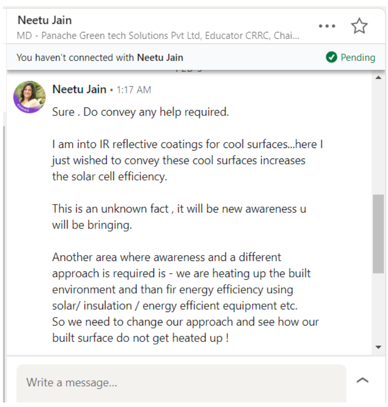


Organization name : Panache Cool roofs

Key Individual : Neetu Jain

Designation : Managing Director

Industry : Roof cooling paints supplier/ manufacturing



Appendix

Bonafide Certificates

The bonafide certificates of all our teammates are attached below.

ORIGINAL

SCHOOL OF PLANNING AND ARCHITECTURE
JAWAHARLAL NEHRU ARCHITECTURE & FINE ARTS UNIVERSITY
MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 635 Date 21/02/2023

BONAFIDE CERTIFICATE

This is to certify that P. Jayashree
S/o/D/o P. Shanker Roll No. 19011AA001
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

PRINCIPAL
Mahaveer Marg, Hyderabad - 500 028. T.S

ORIGINAL

SCHOOL OF PLANNING AND ARCHITECTURE
JAWAHARLAL NEHRU ARCHITECTURE & FINE ARTS UNIVERSITY
MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 644 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that N. Nikhil Kumar
S/o/D/o N. Prabhakar Roll No. 19011AA032
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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Serial No. 645 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that K. Chakravarthy
S/o/D/o K. Ramaraju Roll No. 19011AA036
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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Serial No. 646 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that R. Rohan Kumar
S/o/D/o R. Sreenivasulu Roll No. 19011AA040
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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Serial No. 636 Date 21/02/2023

BONAFIDE CERTIFICATE

This is to certify that Pranav Raghavan
S/o/D/o R. Veera Raghavan Roll No. 19011AA003
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 637 Date 21/02/2023

BONAFIDE CERTIFICATE

This is to certify that B. Devendar Goud
S/o/D/o B. Suresh Goud Roll No. 19011AA007
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 638 Date 21/02/2023

BONAFIDE CERTIFICATE

This is to certify that P.S.N.V.D Mani Deepika
S/o/D/o P. Sree Rama Murthy Roll No. 19011AA008
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

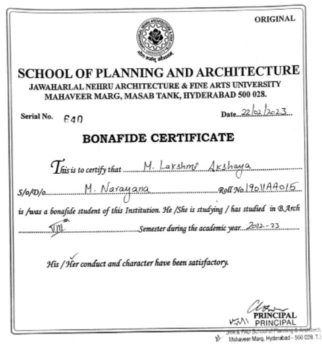
Serial No. 639 Date 21/02/2023

BONAFIDE CERTIFICATE

This is to certify that T. Yateendra Sai
S/o/D/o T. Deena Dayal Roll No. 19011AA009
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

PRINCIPAL
Mahaveer Marg, Hyderabad - 500 028. T.S



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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 640 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that M. Lakshmi Akshaya
S/o/D/o M. Narayana Roll No. 19011AA015
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

PRINCIPAL
Mahaveer Marg, Hyderabad - 500 028. T.S

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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 641 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that D. Anjana Vasuki
S/o/D/o D. Nagesh Roll No. 19011AA021
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 642 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that G. Sri Priya
S/o/D/o G. Suryanarayana Roll No. 19011AA023
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

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Mahaveer Marg, Hyderabad - 500 028. T.S

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MAHAVEER MARG, MASAB TANK, HYDERABAD 500 028.

Serial No. 643 Date 22/02/2023

BONAFIDE CERTIFICATE

This is to certify that K. Reesha
S/o/D/o K. Veera Sampath Kumar Roll No. 19011AA025
is /was a bonafide student of this Institution. He /She is studying / has studied in B.Arch VIII Semester during the academic year 2022-23

His / Her conduct and character have been satisfactory.

PRINCIPAL
Mahaveer Marg, Hyderabad - 500 028. T.S

Appendix

LIST OF INPUT AND OUTPUT PARAMTERS

The list of input and output parameters we used for the enrgy simulation are as follows:-

Input Parameters	Units	Proposed Design Values
General		
Building Area	m²	10047.24
Conditioned Area	m²	5713.57
Electricity Rate	INR/kWh	
Natural Gas Rate	INR/GJ	If Applicable NA
Building Occupancy Hours	-	Example: 7am - 6pm
Average Occupant Density	m² / person	10
Internal Loads		
Interior Average Lighting Power Density	W/m²	10
List of Lighting Controls	-	LED with linear lighting control
Average Equipment Power Density	W/m²	5
Minimum OA Ventilation (Building Average)	l/sec.m²	5
Envelope		
Roof Assembly U value	W/m².K	0.302
Roof Assembly SRI		0.3
Average Wall Assembly U value	W/m².K	0.427
Window to Wall Area Ratio (WWR)	%	30%
Windows U value	W/m².K	1.7
Windows SHGC		0.44
Windows VLT	%	54
Infiltration Rate	ac/h	0.075
Describe Exterior Shading Devices		horizontal louvres
HVAC System		
HVAC System Type and Description	-	Air cooled vrf system with
Describe Mixed mode strategy in operation/controls of AC and windows	-	DOAS(dedicated outdoor air system) mixed mode demand control operation
Heating Source	-	Gas/ Electric etc.
Heating Capacity	kW	
Heating COP		
Cooling Source	-	Gas/ Electric etc.
Cooling Capacity	kW	
Cooling COP		
Operation Hours		Mixed mode operation
Heating Set Point	°C	
Cooling Set Point	°C	
Relative Humidity Setpoint		

Appendix

LIST OF INPUT AND OUTPUT PARAMTERS

The list of input and output parameters we used for the enrgy simulation are as follows:-

Service Hot Water			
SHW Type and Description	-	If Applicable	NA

Output Parameters	Units	Proposed Design Values	
Proposed EUI (Total)	kWh/m²/ yr	56.66	
EUI Breakdown by End Use			
Heating	kWh/m²/ yr	3261.10	
Cooling	kWh/m²/ yr	261715.31	
Fans	kWh/m²/ yr	206440.61	
Pumps	kWh/m²/ yr	0	
Heat Rejection	kWh/m²/ yr	0	
Service Hot Water	kWh/m²/ yr	0	
Lighting	kWh/m²/ yr	56279.05	
Equipment	kWh/m²/ yr	41332.24	
Total Envelope Heat Gain (Peak)	W/m²	57969.6	
Cooling Load of Conditioned Area	SF/ Tr		
Building Electric (Peak)	W/m²	2,05,566.79	
Annual Operating Energy Cost	INR/m²		
Annual Unmet Hours	-	417	
Cooling Capacity	Tr		
Annual Hours of Comfort without Air Conditioning			
Monthly Energy Performance		**Generation**	**Consumption**
Jan	kWh	56,107	36,338.81
Feb	kWh	54,496	33,861.88
Mar	kWh	61,323	45,129.66
Apr	kWh	57,388	51,835.18
May	kWh	56,141	59,911.35
Jun	kWh	41,705	54,168.02
Jul	kWh	36,529	54,834.79
Aug	kWh	37,996	47,548.16
Sep	kWh	45,067	49,192.4
Oct	kWh	53,089	53,448.08
Nov	kWh	50,631	44,241.09
Dec	kWh	50,851	38,518.84

Appendix

CONTEXT ANALYSIS

Site Location

The site is located in Kalyan, Dombivili in the state of Maharashtra in India.

Context

Dombivili is located very near to the Palava city, which is a smart city developed by Lodha group.
Kalyan-Dombivli is also considered one of the fastest developing city after Navi Mumbai.
The site falls under the Seismic zone III which is at a moderate damage risk due to earthquakes.

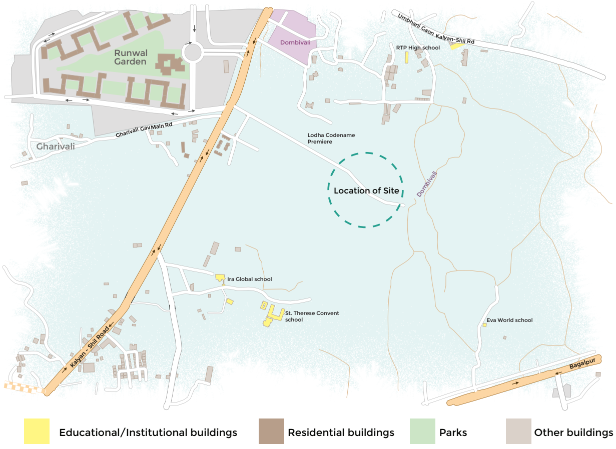


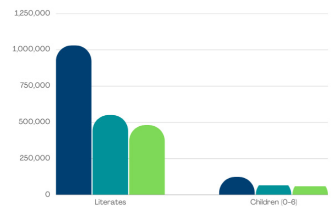
Fig.3 Satellite view of the site

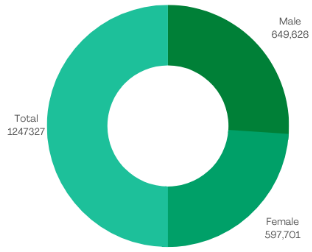
There are a number of schools located near the project site. The names of some of the schools are Ira Global school, St.Therese Convent school, Eva world school, etc. Lodha group has developed many schools nearby this region as part of the development of townships neighbourhoods.

Fig.4 Data for charts from Census 2011. Images taken from Google.

Background Of The People

The literacy rates in this region is high compared to other places. The economic background of people in this region is mostly middle and high income groups. People of this region have a higher per capita income compared to other areas in the state.





Data for literacy rates in the region- Census 2011

Swot analysis of Site

Table 1 data from https://www.btsquarepeg.com/sustainable/materials/local-materials/

Material	Embodied Energy in kWh / m³		
	Production	Transportation	Total
Burnt Clay Bricks	708	2	710
Flyash Bricks	335	55	390

Market Potential

The school would cater to the nearby residential buildings which form part of the neighborhood developed by Lodha group The residential buildings names Lodha Codename Premier consist of 1BHK, 2BHK, and 3BHK flats with sundecks. The school would cater to the people living in these residences.

Local Construction Techniques and materials

Kalyan-Dombivili region has a history dating back to about 400 years ago. The area had an influence of Marathi culture similar to Pune or Nagpur.The urban traditional houses called "Wadas" or "Manzils" reflect the cultural and traditions of the region. Local materials include flyash brick and burnt clay bricks.

Fig.5 Vernacular construction materials

Appendix

DETAILED BUILDING AREA PROGRAMME

Total Site area	: 10947.67 sqm
Built up area(Ground floor)	: 2820.93 sqm
Total Landscaped area	:6081.84 sqm
No. of floors	:6
Total Conditioned area	: 2227.7 sqm
Total Unconditioned area	: 2737.5 sqm
School capacity will be ~ 2,500/2600 students.	

GROUND FLOOR	
Conditioned area	1043 sqm
Unconditioned area	1457 sqm

FIRSTFLOOR	
Conditioned area	245 sqm
Unconditioned area	2255 sqm
Area of toilets	60 sqm

SECOND FLOOR	
Conditioned area	400 sqm
Unconditioned area	2100sqm
Area of toilets	60 sqm

THIRD FLOOR	
Conditioned area	245 sqm
Unconditioned area	2255 sqm
Area of toilets	60 sqm

FOURTH FLOOR	
Conditioned area	245 sqm
Unconditioned area	2255 sqm
Area of toilets	60 sqm

Name of the room	No. of rooms	Total area	Space conditioning
Nursery, jrKg and Sr. Kg	9 (35/36 students each)	480 sqm	Unconditioned (air conditioned to maintain thermal comfort)
I to Std. X	5 each (40 students each)	2670 sqm	Unconditioned (air conditioned to maintain thermal comfort)
Class XI and XII	3 each (40 students each)	320 sqm	Unconditioned (air conditioned to maintain thermal comfort)

Laboratories	Area re-quired	Space conditioning
Physics lab	90-100 sqm	Air conditioned
Chemistry lab	90-100 sqm	Air conditioned
Biology lab	90-100 sqm	Air conditioned
Math & Robotics lab	70 sqm	Air conditioned
Language lab (40 students)	70 sqm	Air conditioned
Technical drawing room	53 sqm	Air conditioned
2 computer labs	90 sqm	Air conditioned
library	140-150 sqm	Air conditioned

Co-curricular activ-ities	Area re-quired	Space conditioning
Multi activity room	70 sqm	Air conditioned
Music room	70 sqm	Air conditioned
Dance room	90 sqm	Air conditioned
Art & craft room	70 sqm	Air conditioned
PE / Sports room / Yoga room	70 sqm	Air conditioned
Resource room	10 sqm	Air conditioned
Counsellor rooms -2	10 sqm	Air conditioned
Special Education Needs -2	15 sqm	Air conditioned

Appendix

DETAILED BUILDING AREA PROGRAMME

Offices	Area required	Space conditioning
Principal office with attached wash-room	25 - 27.5 sqm	Air conditioned
Secretary for principal	7.5 sqm	Air conditioned
Docket room -1	13.5 sqm	Un conditioned
Vice principal cabin -1 with attached washroom	13.9 + 2.7-3.7 sqm	Air conditioned
Workstations for admin staff	13.9 - 13.5 sqm	Air conditioned
Admissions office	23.2 sqm	Air conditioned
Conference room /training room	46.5 sqm	Air conditioned
Pre primary HOD room	15 sqm	Air conditioned
Senior school HOD room	115 sqm	Air conditioned
Staff room – 4 (1 per each floor)	53 sqm	Air conditioned

Support spaces	Area required	Space conditioning
Multi purpose hall (air conditioned) with stage	675 sqm column free space	Air conditioned
Canteen area + pantry	52 sqm	Unconditioned
Medical room/infirmary	44.5 sqm	Air conditioned
Stock room	14 sqm	Unconditioned
Reprography room	14 sqm	Unconditioned
Sports store room	18.6 sqm	Unconditioned
House keeping and maintenance room	14 sqm	Unconditioned
Electrical room	28 sqm	Unconditioned
Cc tv room	18.6 sqm	Unconditioned
Server room	18.6 sqm	Air conditioned

Appendix

FINDINGS FROM PRE-DESIGN ANALYSIS

Climate Analysis

The Climate of Mumbai is a tropical, wet and dry climate. Mumbai's climate can be best described as moderately hot with high level of humidity. Its coastal nature and tropical location ensure temperatures do not fluctuate much throughout the year.

Location - Dombivili, Mumbai
Elevation/Altitude - 11 M
Average precipitation - 242.2 cm (95.35 inches)
Summer (March to May) Avg temperature - 30 to 27 °C
Winter (October to February) winter temperature 15 to 20°C

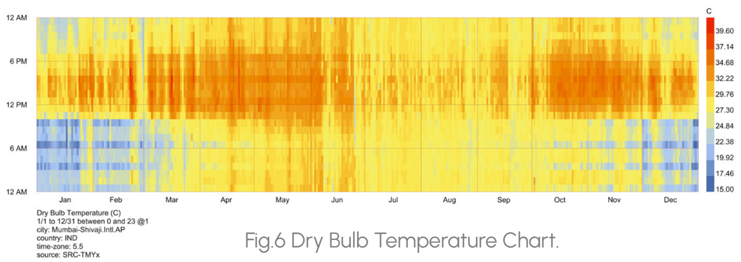


Fig.6 Dry Bulb Temperature Chart.

Temperatures are low during nights in the winter months

The month of August has the highest percentage of relative humidity.

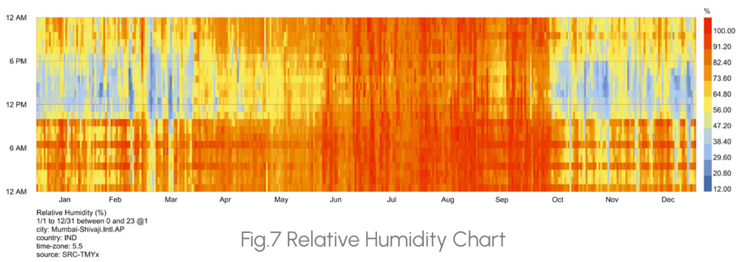


Fig.7 Relative Humidity Chart

Ground temperatures are approximately the same on the surface and at 4m depth also.

Dombivili has hardrock soil type with rocks being found at 2m depth from surface.

Wind rose Chart

Predominant wind direction is from West

The wind flow from west contains more humidity and therefore, requires dehumidification strategies to ensure thermal comfort.

The average temperature range of wind is 27-30^{0} C in all directions.

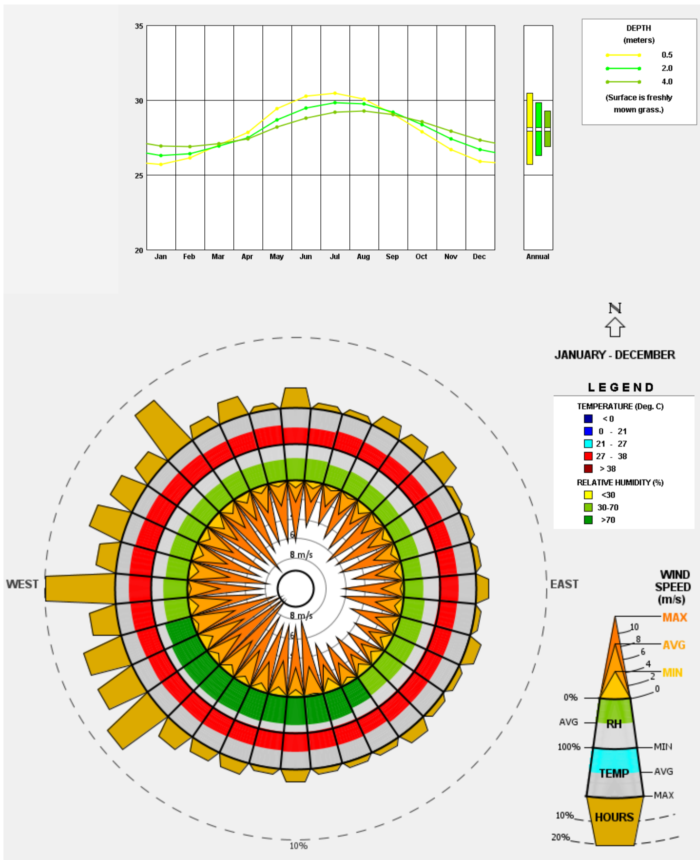


Fig.8 Wind Rose Diagram and Ground temperatures

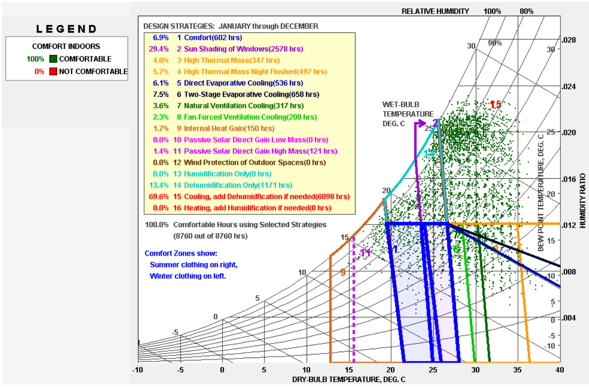
Appendix

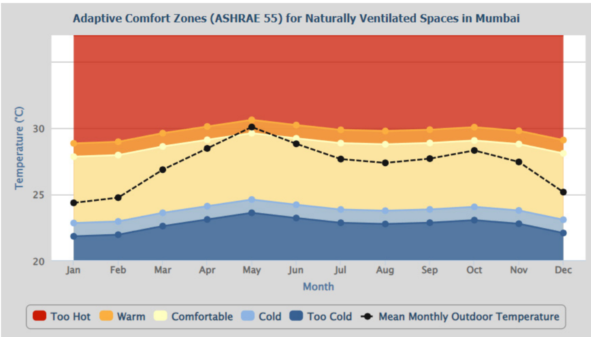
THERMAL COMFORT ANALYSIS

From the psychrometric chart, it can be concluded that to achieve comfort, dehumidification should be done. Use of passive ventilation systems may help in increasing comfort levels.
Direct solar heat gain should be minimized by using extended overhangs, louvred walls etc.

Thermal Comfort Targets

Achieve 20 - 26 degrees Celsius in Winter and 25 - 28 degrees Celsius in Summers





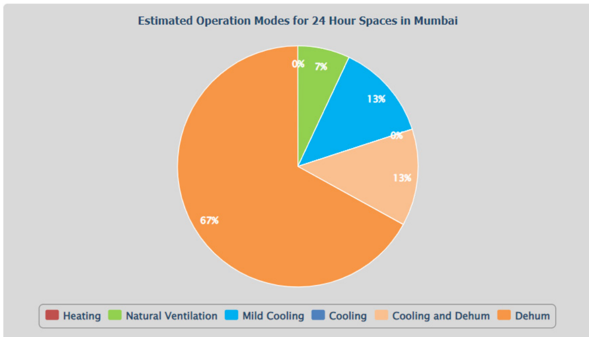
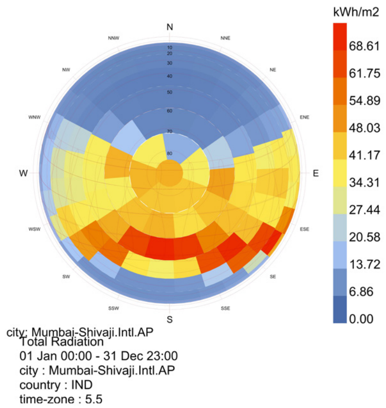


Fig. 9 Comfort charts from IMAC(Indian Model for Adaptive Comfort), CARBSE(Centre for Advanced Research in Building Science and Energy)

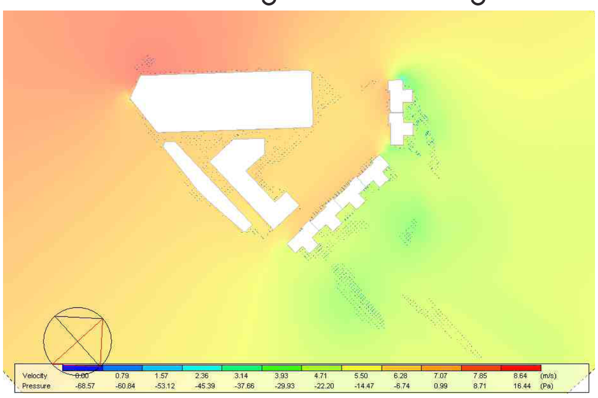
SHADING AN IRRADIATION STUDY

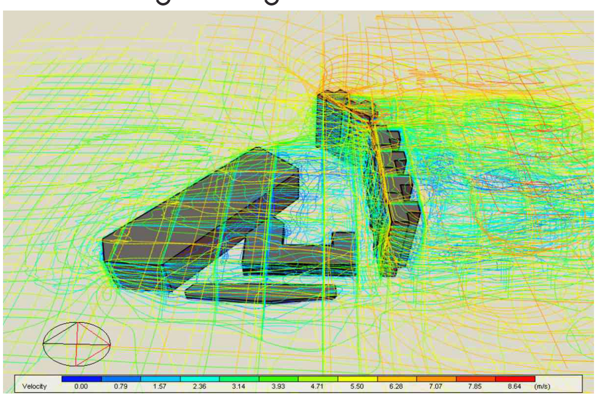
From the Sky dome shading chart, it can be observed that shading devices are required in the South, West and East directions. With respect to the site, only the South facade requires significant shading devices.
Times of the year when shading is required:-
Months of October to February.(radiation is high since sun is closer to the ground surface)
Time of the day shading is required:-
8:00AM to 3:00PM



CFD STUDY

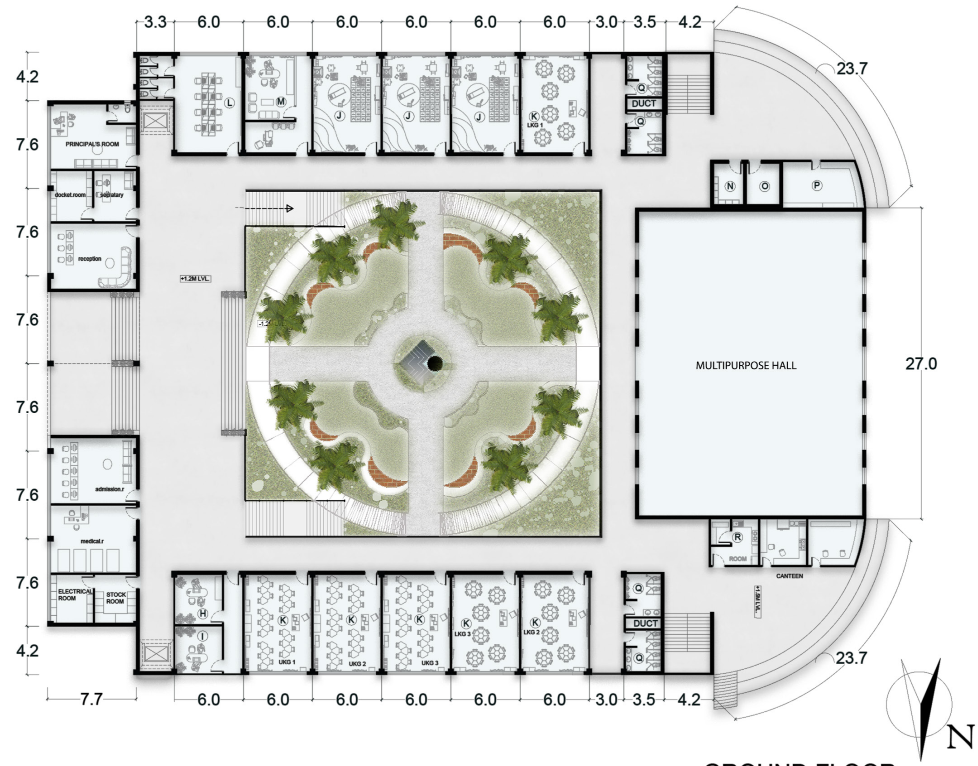
The wind flow through the site is irregular due to surrounding buildings.





Appendix

DETAILED FLOOR PLANS

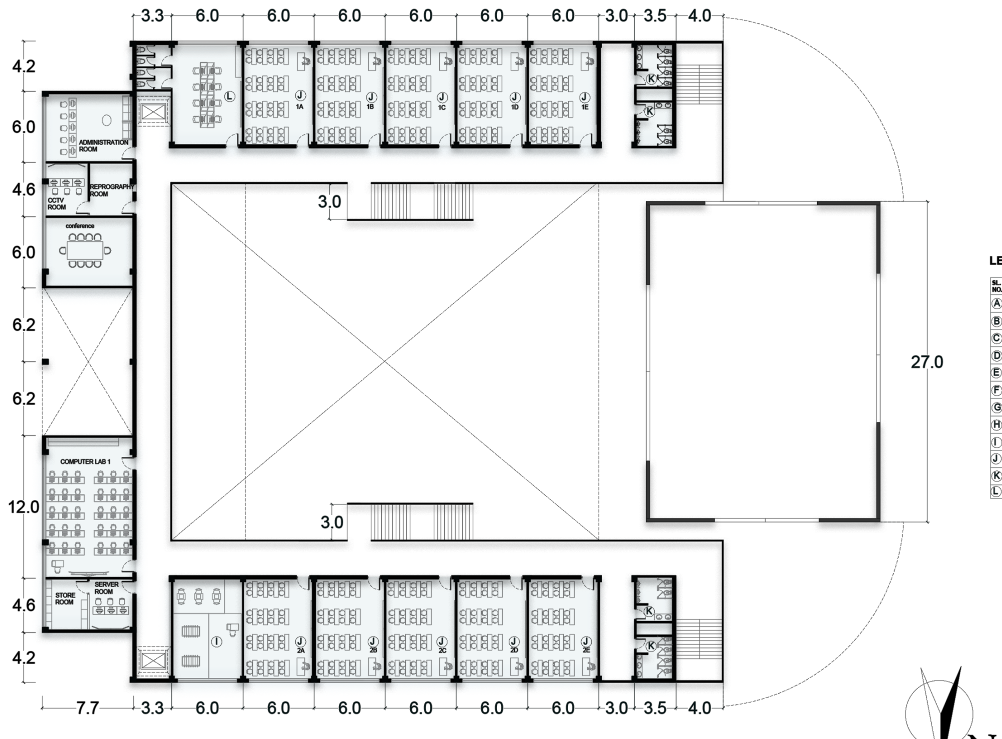


GROUND FLOOR

SCALE-1:200

LEGEND

SL. NO.	SPACE PROVIDED	AREA
A	PRINCIPAL'S ROOM	50 SQ.M
B	DOCKET ROOM	15 SQ.M
C	SECRETARY TO PRINC.	15 SQ.M
D	ADMISSIONS OFFICE	45 SQ.M
E	MEDICAL ROOM/INFIRMARY	50 SQ.M
F	STOCK ROOM	20 SQ.M
G	ELECTRICAL ROOM	30 SQ.M
H	COUNCELLOR ROOM	20 SQ.M
I	SEN ROOM	20 SQ.M
J	NURSERY 1	54 SQ.M
K	LKG UKG	54 SQ.M
L	STAFF ROOM	70 SQ.M
M	PRE PRIMARY HOD ROOM	54 SQ.M
N	LOCKER	12 SQ.M
O	JANITOR ROOM	12 SQ.M
P	MAINTENANCE AND HOUSEKEEPING ROOM	30 SQ.M
Q	GIRLS TOILET/ BOYS TOILET	12 SQ.M
R	PANTRY	15 SQ.M



FIRST FLOOR

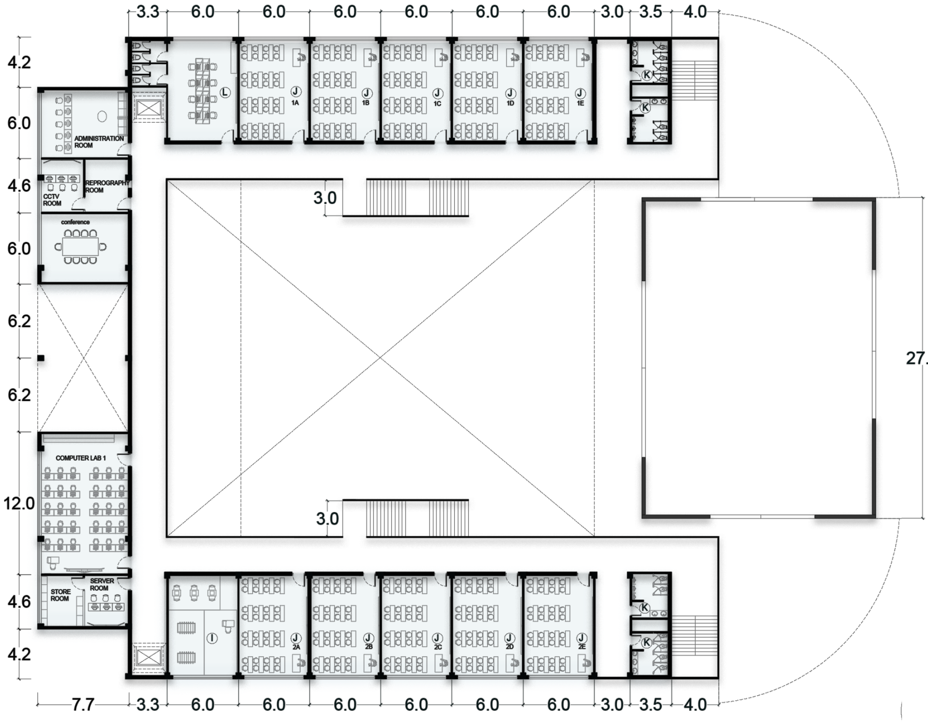
SCALE-1:200

LEGEND

SL. NO.	SPACE PROVIDED	AREA
A	ADMINISTRATION	45 SQ.M
B	CONFERENCE ROOM	50 SQ.M
C	WAITING ROOM	20 SQ.M
D	SPORTS STORE ROOM	20 SQ.M
E	REPROGRAPHY ROOM	20 SQ.M
F	SERVER ROOM	20 SQ.M
G	CCTV ROOM	20 SQ.M
H	ACTIVITY SPACE	90 SQ.M
I	SPORTS ROOM	54 SQ.M
J	CLASSROOM	54 SQ.M
K	GIRLS TOILET/ BOYS TOILET	12 SQ.M
L	STAFF ROOM	70 SQ.M

Appendix

DETAILED FLOOR PLANS

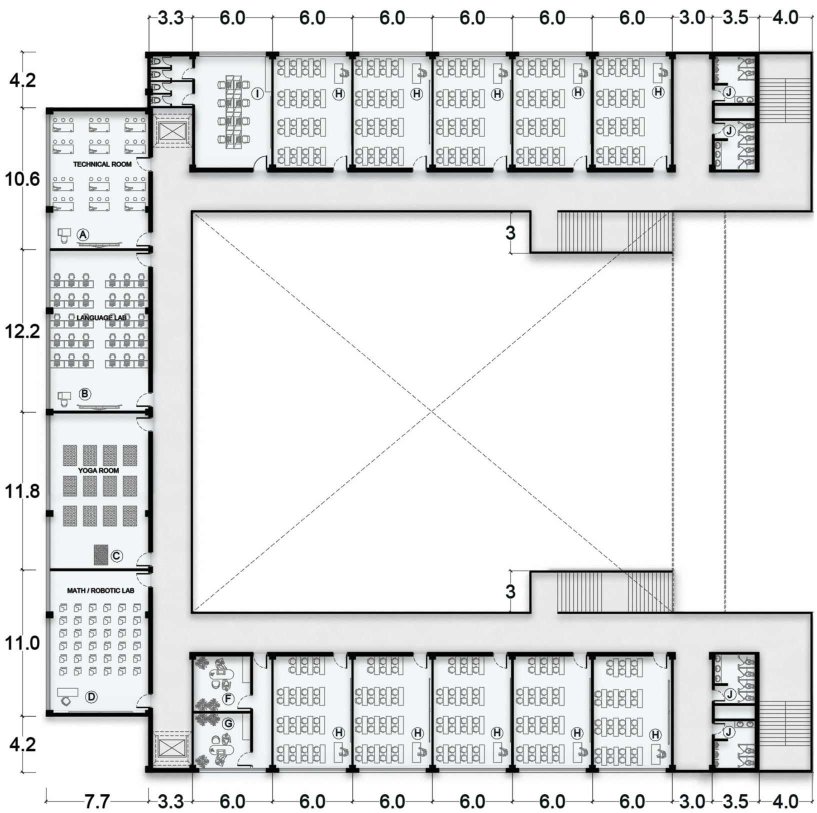


LEGEND

SL. NO.	SPACE PROVIDED	AREA
A	ADMINISTRATION	45 SQ.M
B	CONFERENCE ROOM	50 SQ.M
C	WAITING ROOM	20 SQ.M
D	SPORTS STORE ROOM	20 SQ.M
E	REPROGRAPHY ROOM	20 SQ.M
F	SERVER ROOM	20 SQ.M
G	CCTV ROOM	20 SQ.M
H	ACTIVITY SPACE	90 SQ.M
I	SPORTS ROOM	54 SQ.M
J	CLASSROOM	54 SQ.M
K	GIRLS TOILET / BOYS TOILET	12 SQ.M
L	STAFF ROOM	70 SQ.M

FIRST FLOOR

SCALE-1:200



LEGEND

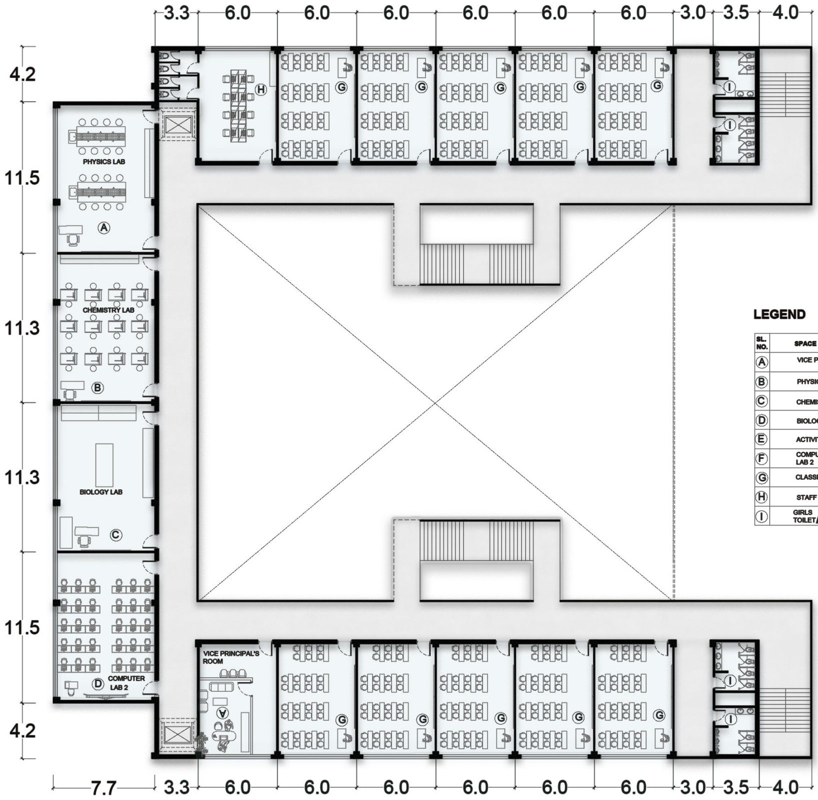
SL. NO.	SPACE PROVIDED	AREA
A	TECHNICAL ROOM	65 SQ.M
B	LANGUAGE LAB	65 SQ.M
C	YOGA ROOM	65 SQ.M
D	MATH / ROBOTIC LAB	65 SQ.M
E	ACTIVITY SPACE	90 SQ.M
F	COUNCELLOR ROOM	25 SQ.M
G	SEN ROOM	25 SQ.M
H	CLASSROOM	54 SQ.M
I	STAFF ROOM	70 SQ.M
J	GIRLS TOILET / BOYS TOILET	12 SQ.M

SECOND FLOOR

SCALE-1:200

Appendix

DETAILED FLOOR PLANS

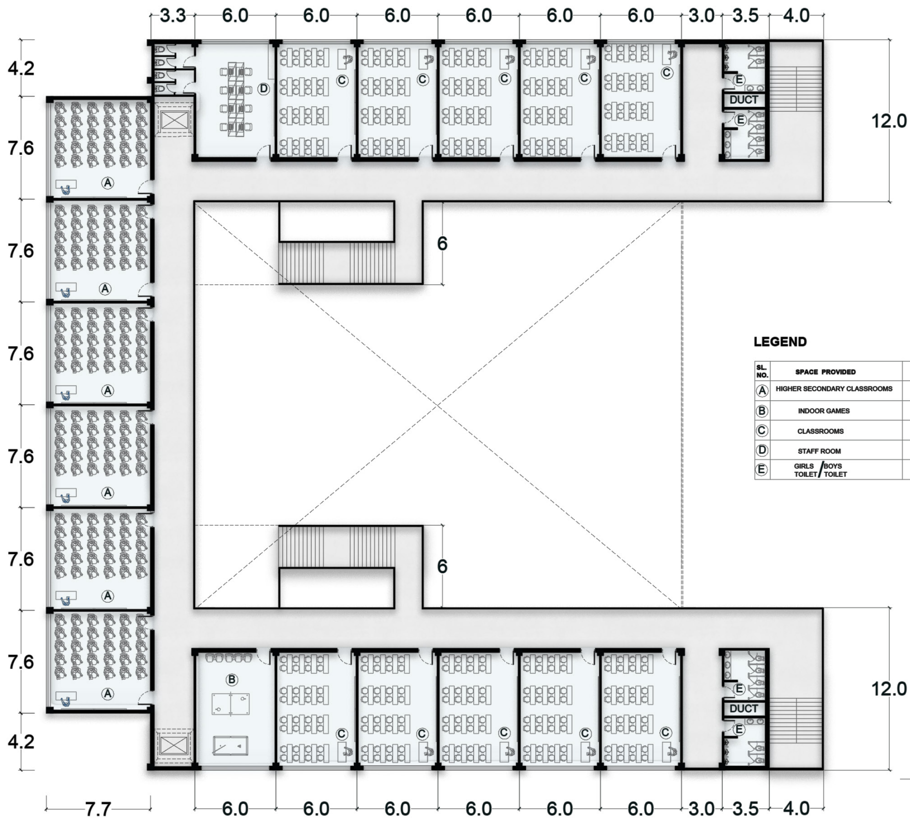


LEGEND

SL. NO.	SPACE PROVIDED	AREA
A	VICE PRINCIPAL'S ROOM	65 SQ.M
B	PHYSICS LAB	65 SQ.M
C	CHEMISTRY LAB	65 SQ.M
D	BIOLOGY LAB	65 SQ.M
E	ACTIVITY SPACE	90 SQ.M
F	COMPUTER LAB 2	54 SQ.M
G	CLASSROOM	54 SQ.M
H	STAFF ROOM	70 SQ.M
I	GIRLS TOILET / BOYS TOILET	12 SQ.M

FOURTH FLOOR

SCALE-1:200



LEGEND

SL. NO.	SPACE PROVIDED	AREA
A	HIGHER SECONDARY CLASSROOMS	60 SQ.M
B	INDOOR GAMES	54 SQ.M
C	CLASSROOMS	54 SQ.M
D	STAFF ROOM	70 SQ.M
E	GIRLS TOILET / BOYS TOILET	12 SQ.M

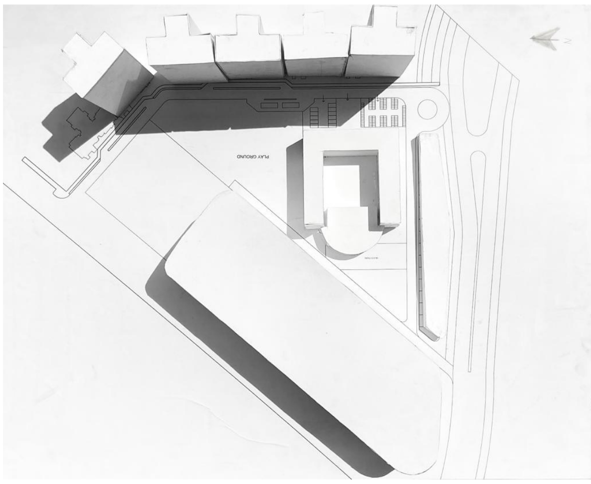
FIFTH FLOOR

SCALE-1:200

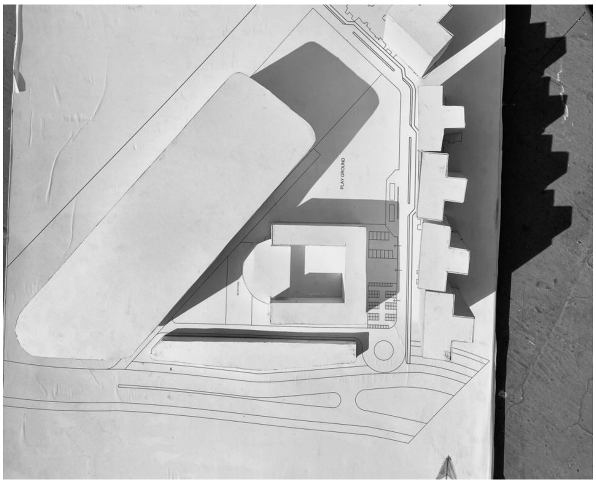
Appendix

PHYSICAL MODEL

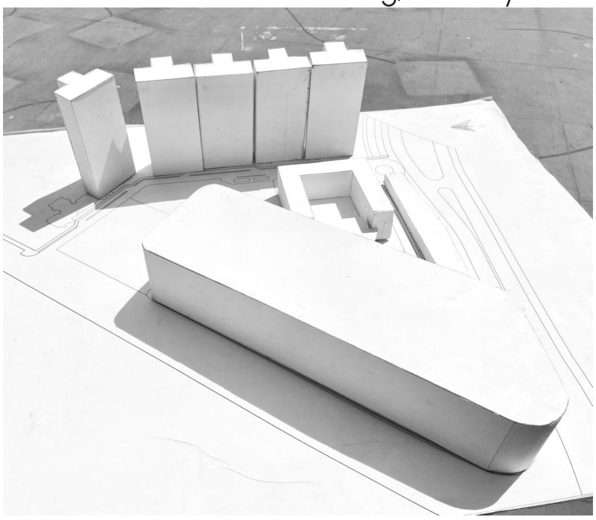
A physical model was created to visualise the design and its site context. Since the project is a part of a larger development, it was necessary to understand how the building would respond to its surroundings.
We also studied the shadows and sciography by placing the building blocks on the site drawing or layout.

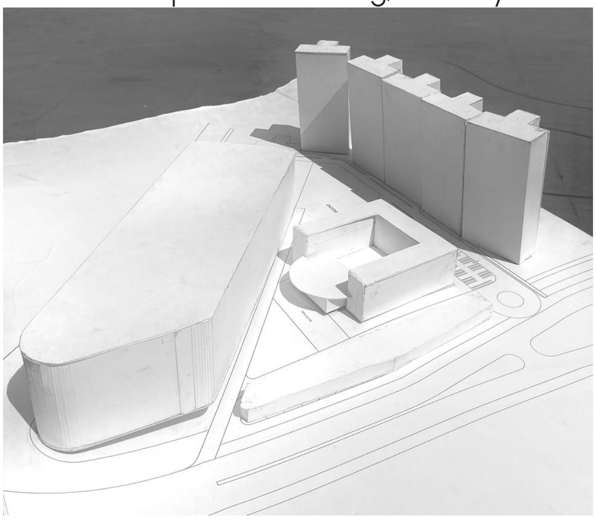


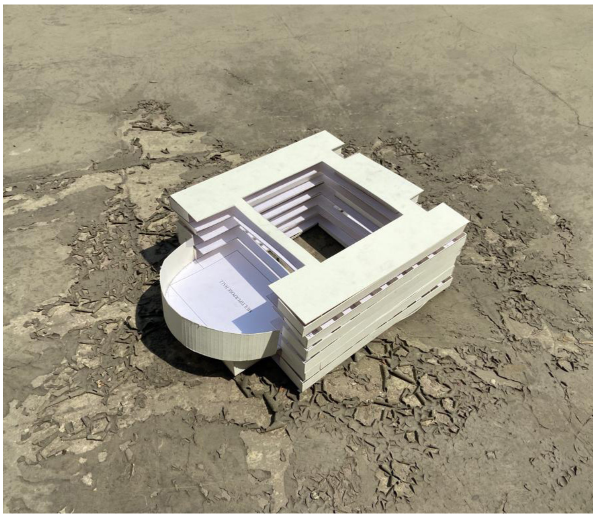
Shadows at 11 am in the morning, February



Shadows at 4pm in the evening, February







Appendix

GROUPWORK AND REVIEWS TAKEN BY THE TEAM

All the team members assembled and took reviews from faculty members and other students in the university for the Solar Decathlon India competition work.
We discussed about the strengths and weaknesses of the project and tried to come up with solutions to make our design better.
With a physical model in front, it was very simple to visualise the project and how it would turn out after getting constructed. We were also able to assess the various parameters that affect and change the overall outcome of the project.

Appendix

Passive cooling strategies

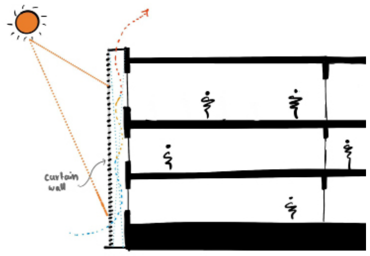


Fig 27

Curtain walls : A curtain wall is used in the south side facade which reduces the solar radiation and helps as cavity. Curtain wall systems are an affordable option for the building exterior casing.This allows for a greater flexibility in design.

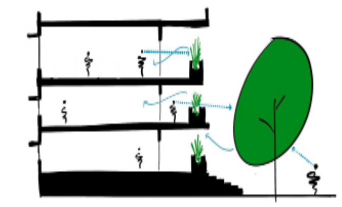


Fig 28

Biophilic design : A Biophilic designed buildings incorporate things like natural lighting and ventilation, natural landscape features.It not only Improves indoor air quality, but also help to revive stress and improve mental well being

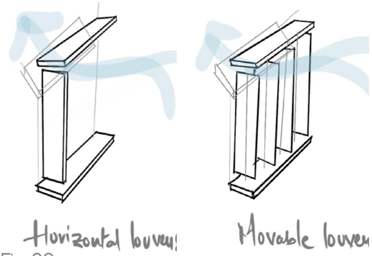


Fig 29

Louvers : Louver systems are installed on most buildings that helps to ensure a smoother intake and exhaust of air, and also to provide stronger resistance against rain and noise intrusion.

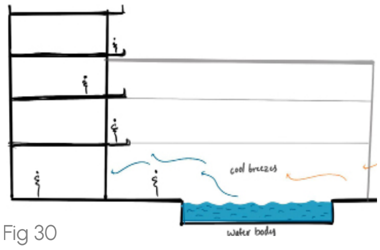


Fig 30

Water bodies : In hot-dry climates, water/ water bodies can be used both for evaporative cooling as well as minimizing heat gain. Taking into account wind patterns and vegetation they can be used to direct cool breeze into the structure.

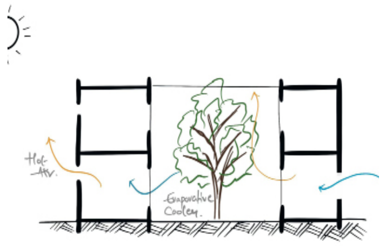


Fig 31

Courtyard : Passive cooling techniques like courtyard planning are very effective in maintaining indoor and outdoor thermal comfort conditions that enhances the micro climatic conditions of the structure.

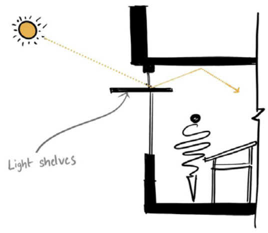


Fig 32

Light shelves : A light shelf is a passive architectural device used to reflect natural daylight into a building. They are generally found on walls facing the sun, as on 'pole-facing walls' would tend to act only as sunshades.

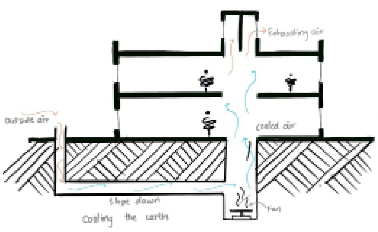


Fig 33

Earth tubes : Earth Tubes are a passive technology that enable the transfer of ground source energy to heat or cool ventilation air. They are standard concrete tubes that run underground and precondition the temperature of incoming air before it enters the building.

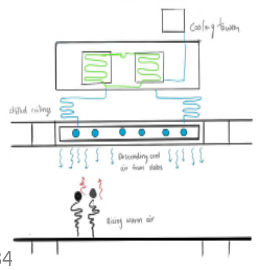


Fig 34

Radiant cooling : The radiant cooling system uses polymer pipes or coils installed within the walls, floors, and ceiling. The coils are circulated with chilled water to cool down the surfaces

Structural systems

COMPOSITE BEAMS WITH WEB

Span range = 10-16m
Web openings are typically formed in beams to allow services to pass through the beam. This enables the structural and service zones to occupy the same space, thereby reducing the effective overall depth of floor construction for a given spanning capability.

CELLULAR COMPOSITE BEAMS

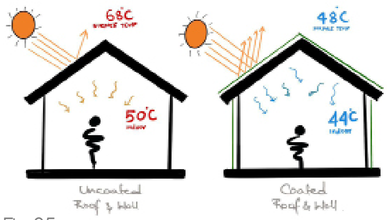
Span range = 15-30m
Cellular composite beams have circular web openings.
Advantage: Preferred over castellated beams since it offers versatility.
Castellated beams have hexagonal web openings.
Limitation: Offer a certain type of aesthetics, Lack of flexibility

COFFERED SLAB

Spans upto 16m
Longer spans may be possible with post tensioning.
For the maximum efficiency, coffers should be square or nearly square as possible. Waffle slab can be efficiently cantilevered in two directions up to 1/3 of a main space.

Appendix

Building Materials research

Material name:	Description of material:	Product company name:	Applications:
Paints	-**Cool Tops Premium** is a 5 coat system using 3 different products : - Cool guard - Cool tops - Transeal  Fig 35 -**Cool Wrap** is a high SRI wall paint which helps reduce the temperature of the buildings by up to 10-15°C on the surface and 3-4°C internally.	**Panache,** creating cool green cities.	-Roofs. -Exterior walls. -Pavements.
Paver blocks/ tiles/ planter	**Construction and demolition waste**:-building material debris and rubble resulting from construction. -Repair and demolition of any civil structure like buildings, roads, culverts etc. are processed and converted into recycled building materials.	Construction and demolition waste recycling services by **RAMKY GROUP**, towards sustainable growth .in partnership with GHMC {Greater Hyderabad Municipal Corporation}	-Pavements. -Planters -Soil -Brickbats -Aggregates (20mm). -Aggregates (10mm).
Drywall partitions.	-Acoustic insulated drywall. -It is made of fiber cement boards with fiberglass wool insulation for acoustic properties.	**Twiga drywall acoustic insulation.**	Used for partition wall systems
Compressed Straw boards/ panels	-Straw compressed to make panels.	E3 wood WPC by E3 extrusion inc.	Decking, wall cladding, louvers, furniture etc.
Roof Tiles	-**Rocotile** is a certified 'eco-friendly' by Green Building Initiative.	**Rocotile** , roof cool tiles.	Used on terrace.

Appendix

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