Solar™ Decathlon India

ORD TOWERS

SCHOOL OF PLANNING AND ARCHITECTURE NEW DELHI

Polymorph

Educational Building

Final

Design Report

Final Design Report - April 2021

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Polymorph is a multidisciplinary team from SPA Delhi. We are a team of architecture and engineering students, guided by experienced professionals from illustrious backgrounds. Each member of the team has a unique design perspective and has harmoniously worked to arrive at a proposal that meets the goals of the Decathlon.

We began by designing iterations based on our initial study of the site. From January, one iteration was chosen by the faculty leads in consultation with external jury members to be developed further by the entire group to achieve the goal of a net-zero proposal. From there on, each member was responsible for undertaking the responsibility for one of the 10 contests and worked with the rest of the group members to achieve it.

All guidelines of an IB school were followed such that the design catered to a safe and creative environment for the development of children. We designed spaces interspersed with courtyards that not only enhance the experiential quality of the school, but also aid as a passive strategy, reducing cooling loads.All design decisions such as classroom orientations, size of windows and shading, size and placement of courtyards were done keeping in mind the energy aspect and were arrived at through simulations. Furthermore the building premises was fabricated with interactive stepped landscapes and self cleaning,anti bacterial louver facade systems to ensure a holistic approach to the open environment.

With solar PV panels producing a surplus energy of 25707.047 KWh our school is a Net Zero Energy building .The excess energy so produced will be sold at a profit which will be utilized in the operational and maintenance costs of the building making the net OPEX minimal. The proposed design enables net zero water through a two fold method- reducing the amount of water consumed and reharvesting the storm and wastewater. With a highly energy efficient HVAC system, there would be a much lower cooling load as compared to the estimated cooling load of the base. The 200 TR difference is accredited to the more efficient building envelope and reduced cooling loads. The net result of both strategies applied would help in reducing the operational cost of the building as the utility cost will be zero.

To make this project viable, the team has collaborated with various industry experts and local companies. One of the value points is that all systems used are readily available in India, thus negating all extra import taxes.Furthermore there is a massive annual saving in the operational costs of the building and also additional revenue through the sale of surplus energy.The chilled water and radiant cooling system used come up to 18% in savings in 20 years when compared to a VRF system. The PV panels installed give us 78.15% in savings in 20 years as opposed to using electricity from the grid. The solar panel has a payback period of 3.17 years when considering the savings from annual electricity bills.

Thus, through such innovative strategies, we have achieved a net positive and water conscious design without losing out on the architectural design aspect of the building. This process has led us to a solution that has achieved not just net-zero, but net-positive energy status.

6. Team Introduction

Team Name : Polymorph

Institution : School of Planning and Architecture - New Delhi

Division : **Educational Building**

Team members	Qualification	Role
Aryaman Kashyap	Student (B.Arch)	Solar analysis and Shading
Hardik Mittal	Student (B.Arch)	Energy Simulation and Modelling
Joseph Mathew Aerathu	Student (B.Arch)	Thermal Comfort and Quality
Mahanth Ranganath	Student (B.Tech)	Building Envelope
Muskaan Sandhu	Student (B.Arch)	Architectural Design
Pooja Muralidharan	Student (B.Arch)	Scalibility and Affordibility
Preyanshu Pardhi	Student (B.Arch)	Water Performance & Materiality
Soumia Gupta	Student (B.Arch)	Passive Strategies and Resilience
Subhadeep Sarkar	Student (B.Arch)	Team Lead , Architectural Design
Suprem Nalkund	Student (B.Arch)	Engineering Design and Operation
Vithika Seth	Student (B.Arch)	Structural Engineering

Approach : As a team, the foremost task for us would be to create a homogeneous group where all members can put forth their best skill sets. The design has been approached by dividing the group into 5 sub-groups so that 5 different iterations of the school may be considered, leaving no possibility unexplored. At the initial stage, the designs are discussed and analyzed in order to take the best out of them all and combine them into one for further development into the final design solution for the school.

The institution : School of Planning and Architecture, New Delhi, is a premier higher education federal institute, specializing in education and research, and serving as the national center of excellence, in the fields of planning and architecture. The institute primarily offers:

- Undergraduate Degree in Architecture and Planning
- Postgraduate Programs
- Doctoral Programs
- Executive Education Programs

The Faculty :

- Dr. Shweta Manchanda (Lead Faculty)

She is an architecture faculty at the SPA, New Delhi, specialized in Urban Design and Sustainability. She did her B. Arch from the SPA New Delhi, and her M. Phil and PhD. from the University of Cambridge.

- Dr. Deepti Gupta

She is a visiting faculty at SPA, New Delhi. She did her B.Arch. from SPA, in 1990. Masters in Engineering from Anhalt Hochschule, Germany. PhD, Singhania University, Rajasthan.

- Ar. Kinshuk Aggarwal

Kinshuk Aggarwal of SSSA Architects, did his B. Arch from USAP, Delhi, following which he completed his masters from The Bartlett, UCL, London, in ‘Sustainable Urbanism’.

Project Name : ORD International School

Project Partner : ORD Towers

- **Description**
- **Key Individuals** Mr. Deepanshu Gupta (CEO)

The ORD group Mr. Deepanshu Gupta (CEO)
The ORD group was founded by Rajesh Gupta and Deepanshu Gupta who were among the founders of the Okaya Group and Microtek. Okaya is among the top three battery brands of India and Microtek, the No 1 Inverter brand in the country. Now they have collectively brought their vision into the ORD group to make it yet another successful brand. Their goal is to deliver platinum green LEED certified buildings in the most cost efficient way possible in the industry.

Context

Context :

The site is located in Noida's Sector 134. It is an upcoming sector in the micro-market of Noida Expressway. Enclosed by Sectors 129, 132 and 133, this sector is undergoing residential development, largely in the form of high-rise apartment complexes - namely Jaypee Kosmos, Jaypee Wishtown Klassic and Jaypee Klassic Heights. An emerging sector, the social and retail infrastructure within the sector is still developing. It is just 2 km off the vital Noida Expressway and is therefore well-connected with the rest of Noida.

Market Analysis :

The target audience of the ORD International school would be upper and middle class students of the age group 3-18 years. The majority working population belongs to the service and business sector. Furthermore, there is also an expat community interspersed near the location. Hence, an IB board school would enable their children to study in a familiar international curriculum to facilitate higher studies abroad. The maximum percentage of land use has been dedicated to residential components wherein a lot of high income group families dwell.

Site

The site is located in JP Wish-town Sector 128, Noida. Noida has a composite climate with long and hot summers (average temperatures near 38 ° C and occasional heat waves) and cold winters (average temperatures around 6–7 °C). It receives an annual rainfall of 700 mm. Winds during monsoons are fairly strong and steady (June-July).The remaining months are comparatively calmer. Directional changes in the prevailing winds at the beginning of the warm-humid season bring rain-clouds and humid air from the sea.

- **Special Requirements Of The Client :**
  - The client is also interested in having modular spaces for the school so that future expansions or modifications can be done conveniently.
  - The client expressed his desire of dividing the school into 3 phases as per the Ananda, Jigyasa, and Sadhana nomenclatures.
  - The client expresses that consideration should be given for good lighting strategies that ensure optimum eye comfort. Additionally, proper disposal, handling, and processing of different types of waste generated in the school should be thought out.

- It was imperative to the project partner that the school has a lower operational cost as after the construction, he expects to lease the building to a third party, who would take care of the management of the school. The project partner realizes that a Net Zero Energy Building would have a high CAPEX but he is also expecting a low operational and maintenance cost in the years after construction. The project partner had placed the budget at ₹ 55,000/m2 for the construction costs, we have managed to keep our construction cost at ₹ 41,000 /m2 .

• AREA PROGRAM

Site Area : 15 256 m2
Total number of parking : 152 ECS
Total occupancy : 2400 Built - Up Area : 22 150 m2
Area Per User : 8.57 m2 FAR : 1.5 per user
Height Of The Built-Form : Max. Ground Coverage : 4395 m2 18.6 m
Green Building : 5% FAR + Circulation : 30 %
Landscape area : 2620 m2
Fire Tender Path Width : 6 m Setbacks : Front - 12 m Other - 7.5 m

CLASS	GRADES	STUDENTS/ CLASS	NO. OF SECTION	AREA/ CLASSROOM (sq.m)	TOTAL AREA
Kindergarden	2	20	2	56	224
PYP	5	25	7	56	1960
MYP	5	25	7	56	1960
Diploma	2	N/A	5	56	560

ADMINISTRATION	AREA (sq.m)
Principal Office + PA Desk	20
Headmistress Office	20
Vice Principal Office	20
Meeting Room	50
Record Room	30
Accounts+ General office	120
Reception+ waiting area	130
Counsellors' rooms	25

LABORATORIES	AREA (sq.m)
Computer Lab Senior	112
Language Lab	56
Jr. Science Lab	56
Maths Lab	56
Physics Lab	112
Chemistry Lab	112
Biology Lab	112
Design and Tech Lab	112

ACTIVITIES	TOTAL AREA
Music Room	112
Dance Room	112
Art Room	112
Audio/Visual Room	112
Senior Library	112
Junior Library	112
Canteen	200
Theatre	56

STAFF ROOMS	DIVISION	AREA
Kindergarden	1	56
PYP	1	112
MYP	1	112
Diploma	2	56
Toilets	5	31

TOILETS	
0.2 m2 per student	920
Janitorial Room	160
Administration	30

SPORTS	TOTAL AREA
Sports Field	868
Jr. Sports Field	393
Auditorium	610
Swimming Pool	762
Changing Rooms	200

TABLE 1

- Project Details

Project Location – JP Wishtown, Noida Sector 128, Uttar Pradesh
Climate – Composite
Project Type - Institutional
Occupancy - 2400

CLIMATIC DATA	
Latitude	8°36'36'' N
Maximum Temperature	45 °C
Minimum Temperature	38 °C
Precipitation	700 mm annual rainfall
Average RH levels	30-90%

- Specifications Table

BUILDING SPECIFICATON	
CATEGORY	**DESCRIPTION**
External Wall	100 thck weather proofed cellulose insulation sandwiched between 100 thk and 150 thk AAC blocks from the exterior and interior respectively, R-Value - 0.233
Roofs	40 thk brick tiles covering 180 thk all weather proofed cellulose insulation placed over 50 thk cement screed laid over 150 thk waterproofed slab, R-Value - 0.213
Floor	RCC SLAB (M25, 150 thk) with 80 thk floor finish
Window	AIS Ecosense Clear Sparkle 6-12-6, SHGC- 0.25, VLT -0.46, U-Value-1.6

- Services Table

BUILDING SERVICES	
CATEGORY	**DESCRIPTION OF SERVICES**
Waste Water Recycling	Anaerobic baffled reactor (ABR) for grey water treatment, and aeration and seperation tank for black water
HVAC	Chilled Water System with Radiant Floor +Fresh Air Handling Unit COP - 6.2 (IPLV -10.7)
Lighting and Appliances	18 Watt Concealed Slim LED Panel For Ceiling Light Round/Shape LPD - 2.4 (Classrooms), 2.16 (Labs), 1.42 (Staircase)
Lifts	Thyssen Krup 15-person Meta-Hundred lifts with speed 350 fpm Traction MRI Lift
Electrical	BEE Rated Appliances, Low flow rate water fixtures EPD - 7.47 (Classrooms), 16.97 (Labs), 71.6 (Kitchen)
Renewable Energy Generation	Luminous 24330 Solar Panels, Wattage-330 W, Size-1.976m x 0.991 m , No of panels used-
Energy Conservation Methods	Courtyard Microclimate, Optimum orientation, Earth Shielding, Optimized envelop, efficient scheduling, Night purge cooling, efficient HVAC System, Bio-swales, Xeri-Scaping

TABLE 2

CLIMATE RESPONSIVE

Goal :

The massing of the site must respond to the unique climatic context of the site and the building massing and geometry is oriented to minimize detrimental effects on quality of interior spaces. And peak heat gain through building envelope (for each AC building individually) should meet the GRIHA Building Envelope Peak Heat Gain Factor thresholds for composite climate - 40 W/m2

Through an efficient building envelope design coupled with a shading design based on direction of sun we have managed to achieve a Peak Heat Gain Factor of 12.54 W/m2

ENERGY PERFORMANCE

Our foremost goal was to reduce the energy requirement for the building while not compromising on the comfort of its occupants. The second goal was to provide an adequate renewable energy system to supplement the energy requirements of the building.

Through strategic passive design measures like the courtyard effect, orientation of built form, shading on windows and the facade, we have tried to lower the building energy requirement and have achieved an EPI of 18.32kWh/m·/ yr. Efficient solar panel layouts have allowed the building to generate 431656 kWh amount of energy, out of which 405948.953 kWh is consumed by the building's energy requirements with a surplus of 25707.047 kWh.

WATER PERFORMANCE

Goal:

The idea was to achieve an institution independent enough to suffice its water demands by having to rely the least on an external source and utilizing the most from alternative on site sources.

Efficient fixtures with downsized flow rates, eg. Aerator flow flow taps for faucets and dual flush system for wcs. Consumption brought down 15873436L from 38815701L. Storm water collected from all hardscapes through drains and from soft scapes with aid of bioswales

EFFICIENT COOLING

Goal:

Strategic school design and operation can improve thermal comfort and improve student health and performance. The indoor operative temperature should be in accordance with the range in ASHRAE adaptive thermal comfort model.The ability for multiple indoor units to operate on the same system simultaneously would ensure that different spaces can be conditioned efficiently based on their specific requirements, which would increase efficiency and decrease energy requirement.

Using the ASHRAE adaptive thermal comfort model the building manages to achieve 54 hours of comfort without Air Conditioning. The total conditioned area is 8297 m2. The classrooms have been designed after multiple CFD analyses to ensure efficient circulation. The air changes in the zones too have been scheduled as per ASHRAE standards to ensure minimum recirculation, ensuring greater thermal comfort and indoor air quality.

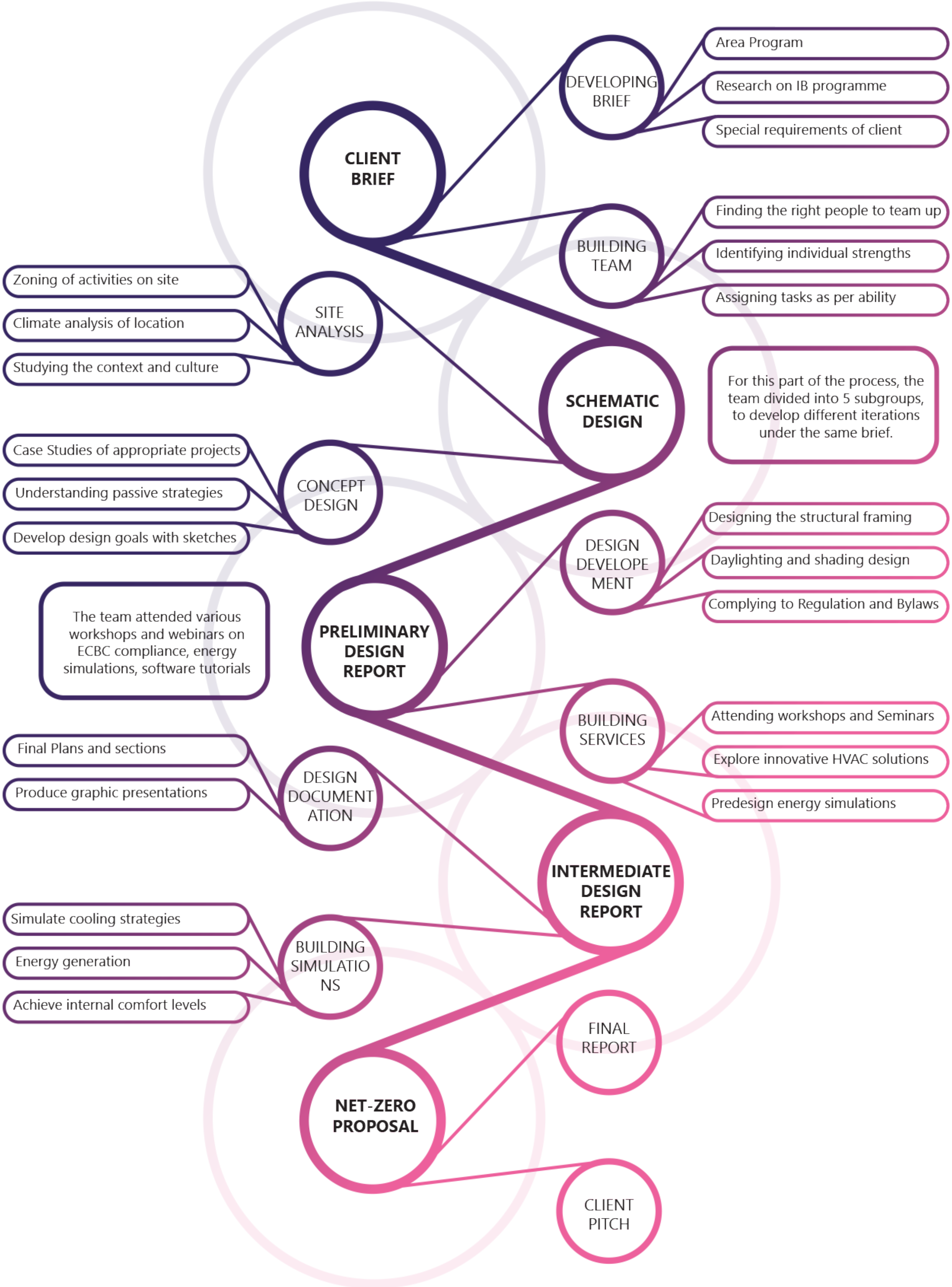


FIG 1: Design Charrettes

September

The team started with studying the working of an IB school and its curriculum to understand occupancy behaviors circulation patterns, and to detail out an area programme. We had the guidance of both teachers and students from IB schools to understand usage of IB school buildings.
The next step was to look into net zero energy buildings and how these buildings reduced the building loads using passive methods.

October

Studying the site was a crucial step into understanding how we can make use of passive methods. Studying the sun and shading patterns, we were able to come up with key directions to take towards a net zero energy design. The group was divided into five pairs of teams, and were expected to come up with five designs out of which one would be chosen by jury members at the end of December.

November

- 2th Nov 2020 - Webinar on ECBC Compliance Through Energy Simulation
- 9th Nov 2020 - Webinar on ECBC Compliance Through Energy Simulation
- 4th Nov 2020 - Webinar on ECBC Compliance Through Energy Simulation
- 30th Nov 2020 - Preliminary Design Report Submission

The team members worked on an area programme for the school based on the study of the IB school done before. This helped the team reach a conclusion on the kind of spaces that we required and their relationship to one another; based on which zoning was done. Which was further developed into plans. The team received guidance from the ECBC seminars, which guided us to inculcate passive design strategies, do preliminary solar calculations.

December

- 29 th Dec 2020 - 30th Dec 2020- External Jury (Jury members - Sanjay Prakash and Ashwini Kumar)

External circulations were planned, bus pick up and drop off were focussed on along with bus, faculty and visitors parking and their relationship with the site.
The jury had given lots of interesting inputs on each of the five iterative designs. One with the most potential to be developed into a net zero energy was chosen.

January

- 11th Jan 2021 - Pre Design Model Chosen
- 15th Jan 2021 - Client Meeting
- 18th Jan 2021 - 1st Feb 2021 - Design Development
- 25th Jan 2021 - Design Builder Workshops by PC Thomas

Out of the five iterative pre-design models, one model was chosen to further develop in terms of architectural design and net-zero performance based on jury comments and further scope of improvement. A client meeting was scheduled to discuss the design model selected and to discuss conditioning strategies and budgetary goals, Structural design and basement design.

February

- 15th Jan 2021 - HVAC Systems Workshop by Abid Hussain

The team split and started taking charge of one of the ten contests towards achieving net zero goals each. HVAC workshops by Abid Hussain, Nishesh Jain and Gaurav Shorey were conducted and attended by all groups. Case study done on Indira Paryavaran Bhawan done earlier was re-visited to study passive and active techniques used. Inculcation of these passive strategies to reduce building loads. Simulations done by students on the respective designs. SLDs and structural drawings finalised. Water and EPI calculations verified with currents designs.

- March

5th March - Client Meeting
30th March - Meeting with Vinod Gupta on Active and passive cooling strategies
Based on the remarks and suggestions on the previous report, the team started reworking on the ten contests of the competitions. A clear water table diagram was calculated. Facade systems were developed further based on materiality. Final working drawings and model for Architectural design were developed. Business model for the project was conceptualized.

- April

2nd April - Showroom visit to LG
The team geared towards the final submission of the competition. Final figures for energy simulations and daylighting were achieved. Structural plans and SLDs were finalized. Project budget and life-cycle costing was derived.

- Tools used :

Drafting- Autocad , Rhino
Massing and 3D modelling- Sketchup, Rhino3D
BIM - Autodesk Revit
Energy Simulations - Design Builder, Edge App, Formit, Solar PMV tool, Andrew Marsh, Insight360

- **Challenges :**

- Working on an on-line platform:

The ongoing pandemic has forced all colleges to shut down and operate virtually. This was a challenge faced by us as a lot of the design process involves working together, sketching ideas on sheets etc. We tackled this issue by meeting up regularly through google meets and zoom calls. We held design ideating sessions on jamboards and Microsoft whiteboards to meet up to this challenge.

- Contacting industry partners to team up:

Contacting industry partners who were willing to team up for our project and lend us their resources was a big challenge for us. Often, the companies we contacted did not get back to us or could not provide us with the necessary resources. We tackled this issue by using the contacts our faculty provided from their field experience as well as sourcing multiple contacts on our own.

- Competition work along with Academic work:

While the solar decathlon submissions were a part of our Design course, we had to balance the time we gave to this project along with academic work from other subject courses. Our lead faculty decided to incorporate certain aspects of the deliverables into our other subjects as well. All in all we had to balance the time we dedicated to other subjects as well as the competition work.

FIG 2: View from the central of the School

INTRODUCTION TO DESIGN

The design of the school is a layered assembly of our vision of an IB school integrated with green systems to achieve a net zero building. The spatial layout was done in such a way that the spine served as a core concept in materializing the built environment. It was based on a simple and clear fundamental principle of differentiating the Junior and Senior block in the school, whilst connecting the entire building via the spine which would essentially simulate a social hub - containing common areas, including a foyer, sports facilities, a canteen etc, within the school. The spine bleeds into the corridor and courtyard spaces of each block, thus propagating the idea of extending learning beyond a classroom with breakout spaces and co-learning spaces, as in an IB school. The building premises is fabricated with interactive stepped landscapes and self cleaning,anti bacterial louver facade systems to ensure a holistic approach to the environment. Furthermore, with a pertinent building orientation to reduce heat gain, solar panel installations on the roof to generate electricity and courtyards in each block to facilitate ventilation, the school befits a net zero building approach.

FIG 3a : Landscape

The school campus has been landscaped with curvilinear pathways and stepped planters adjoined with shaded seating spaces for the students, thus enhancing the outdoor environment whilst giving adequate spaces for playing fields.

FIG 3b: Collaborative Spaces

Each corridor of the senior block ends in a open learning, collaborative space where the students interact and unwind.

FIG 3c : Breakout Spaces

Apart from the on-ground futsal and basketball courts, there are two rooftop playscapes located above the canteen and multipurpose hall respectively catering to junior and senior block students.

Ground Floor Plan with Context

Spatially, there are two main blocks which comprise the building, such that each block has a well placed courtyard within it. The North block (the front block) houses the Pre-Primary and the Primary wing, as well as an indoor playing area. The main entrance (formally) is through the North block and hence it has the administrative complex as well as the Principal's office too. It is connected to the South Block via a corridor which acts as the spine of the building. In the South block,along the spine there are rooms allocated for dance,drama, music etc which thus makes it interactive and lively. Moving away from the ground floor to the floors above (in each of the blocks), there are well lit and ventilated classrooms that look into the respective courtyards. The site circulation is such that there is a clear demarcation between the bus,visitor's entrance and basement, which generates a proper drop off zone for the children.

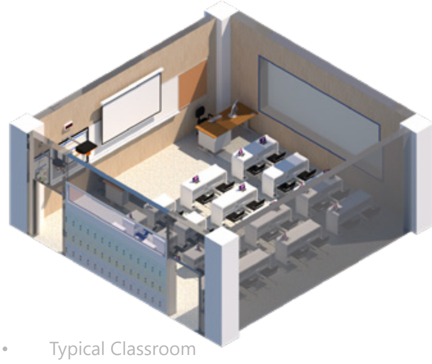
NOTES

- Refer Appendix : Sheet 8 - 15 for Architectural Plans

FIG 4a :

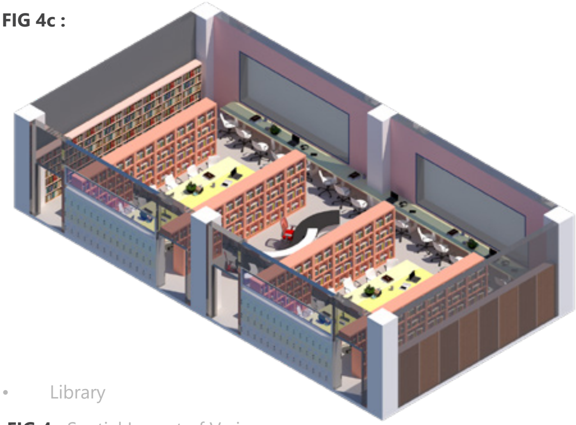
• Pre-Primary Class

FIG 4b :



• Typical Classroom

FIG 4c :



• Library

FIG 4d :

• Staff Room

FIG 4 : Spatial Layout of Various

The PPYP classrooms are essentially interactive to help the children be engaged through the day. The colours in the classroom have been specially kept bright and vibrant to keep the mood upbeat and ___. The class has a clearly demarcated play and reading area that is separated from the study section. The smart board helps the children to understand concepts better and to understand through interactive videos.

A typical classroom in the middle and senior wing is completely technology enabled where each workstation has the ability to be connected to the students' device. The white board has the smart board alongside, making it a perfect amalgamation of chalk and board along with bringing the books alive. The lockers outside the classrooms help the students take ownership of their things and gives them the option of being bag free while at school.

FIG 5 :

NOTES

- Refer Appendix : Sheet 16 for Interior Furniture Layouts

The building facade has been designed as a second screen with integrated shading devices to reduce incoming radiation on the external wall surface. Apart from cutting down solar radiation, the facade also extends the green building performance by passively improving the air quality around it using photocatalytic terracotta louvres with self cleaning and antibacterial properties.
Green wall systems have been spread out over the facade to connect the occupants with nature and aid in improving air quality. The cladding system consists of cement fibre boards with fire and water resistant properties

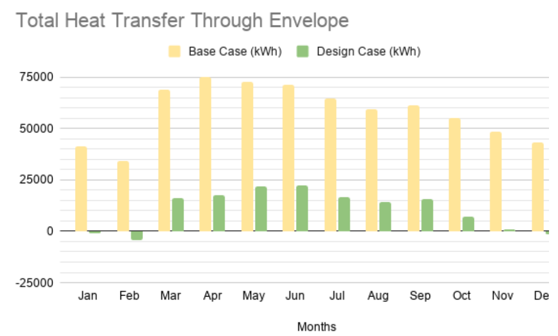


FIG 6 :

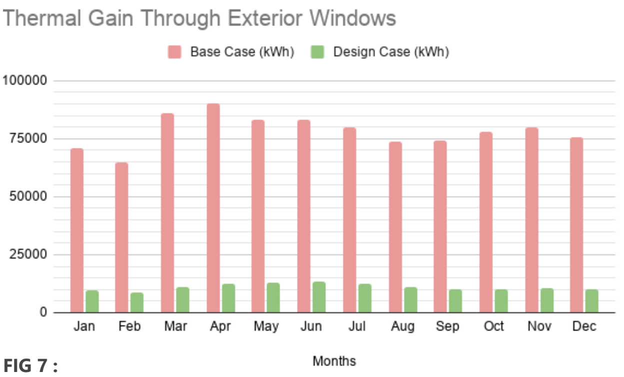


FIG 7 :

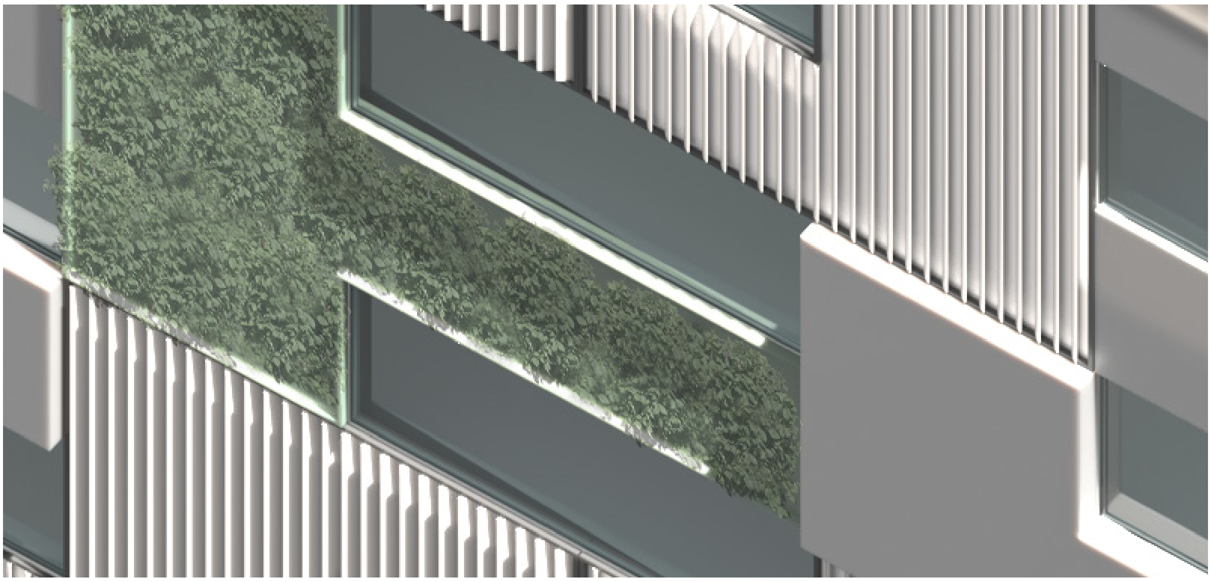


FIG 8 : Facade Elements

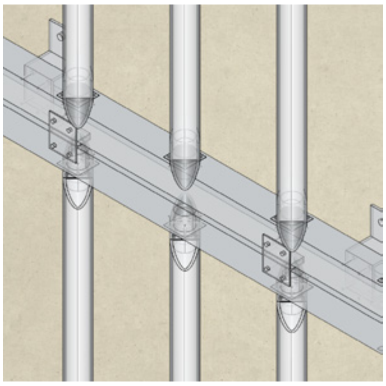


FIG 8a : Terracotta Louvre Detail

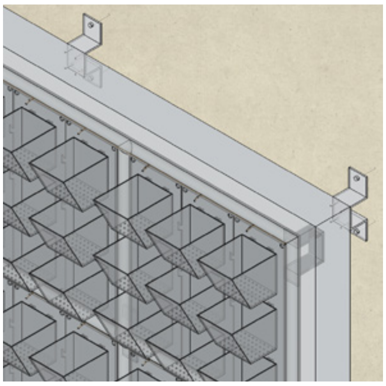


Fig 8b : Green Wall Detail

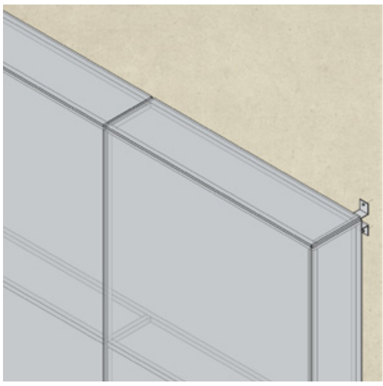
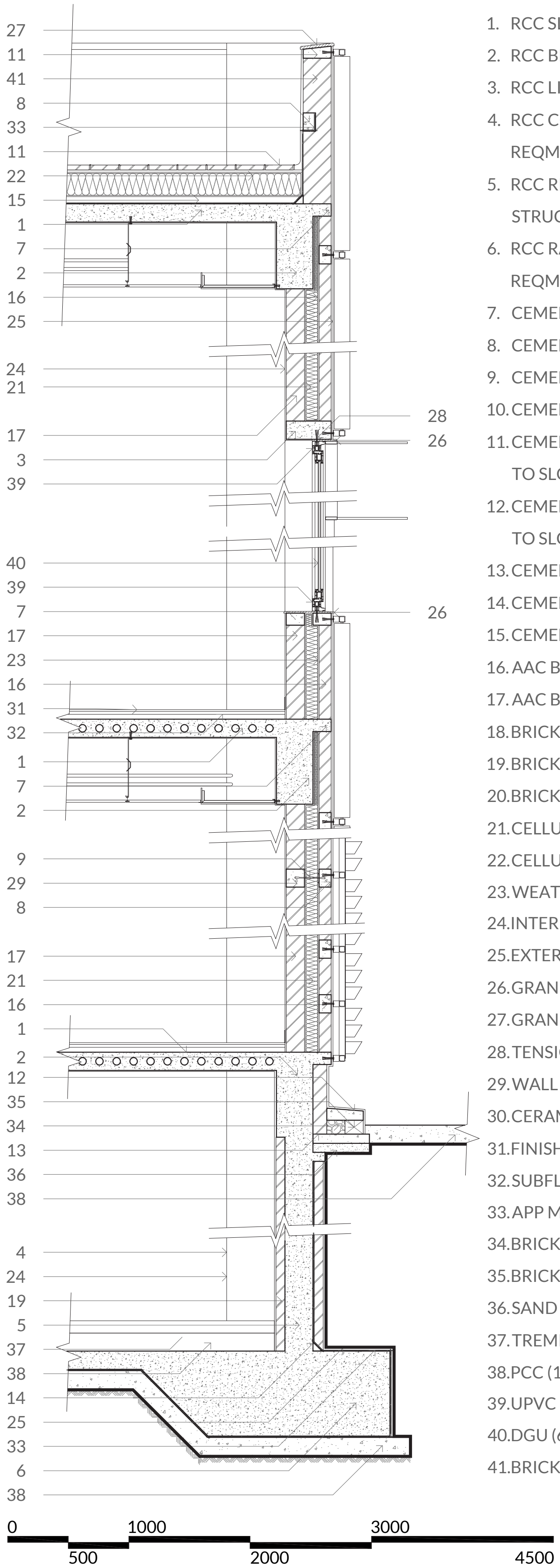


Fig 8c : Cladding Detail

NOTES



1. RCC SLAB (M25, 150 THICK) (AS PER STRUCTURAL REQM.)
2. RCC BEAM (M25, 300x700) (AS PER STRUCTURAL REQM.)
3. RCC LINTEL (M25, 350x150) (AS PER STRUCTURAL REQM.)
4. RCC COLUMN (M25, 700x700) (AS PER STRUCTURAL REQM.)
5. RCC RETAINING WALL (M25, 230 THICK) (AS PER STRUCTURAL REQM.)
6. RCC RAFT (M25, OUT OF 1500x700) (AS PER STRUCTURAL REQM.)
7. CEMENT CONCRETE NIB (M25, OUT OF 150x100)
8. CEMENT CONCRETE BLOCK (1:2:4, OUT OF 100x150)
9. CEMENT CONCRETE BLOCK (1:2:4, OUT OF 150x150)
10. CEMENT CONCRETE BLOCK (1:2:4, OUT OF 150x100)
11. CEMENT CONCRETE BLOCK (1:2:4, OUT OF 230x100, LAID TO SLOPE)
12. CEMENT CONCRETE BLOCK (1:2:4, OUT OF 300x100, LAID TO SLOPE)
13. CEMENT CONCRETE BLOCK (1:2:4, OUT OF 450x75)
14. CEMENT CONCRETE FILLET (1:2:4, OUT OF 75x75)
15. CEMENT SCREED (1:3:6, 50 THICK)
16. AAC BLOCK (100 THICK)
17. AAC BLOCK (150 THICK)
18. BRICK TILE (230x40)
19. BRICK WALL (75 THICK, BRICK ON EDGE)
20. BRICK WALL (115 THICK)
21. CELLULOSE INSULATION (100 THICK)
22. CELLULOSE INSULATION (180 THICK)
23. WEATHERPROOF SHEATHING
24. INTERNAL PLASTER (VERMICULITE BASED, 12 THICK)
25. EXTERNAL PLASTER (VERMICULATE BASED, 15 THICK)
26. GRANITE STONE (15 THICK)
27. GRANITE STONE (25 THICK)
28. TENSION STUD (120 LONG)
29. WALL TIE (250 LONG)
30. CERAMIC TILE SKIRTING (8x100)
31. FINISHED FLOORING (POLISHED CONCRETE)
32. SUBFLOOR (40 THICK, AS PER REQM.)
33. APP MEMBRANE WATERPROOFING
34. BRICK BATS FILLING (OUT OF 150x115)
35. BRICK ON EDGE (150x115)
36. SAND FILLING (OUT OF 450x75)
37. TREMIX (1:1:2, 100 THICK)
38. PCC (1:4:8, 150 THICK)
39. UPVC EXTRUSION, OPENABLE WINDOW FRAME
40. DGU (6-12-6) (AS PER REQM.)
41. BRICK WALL (230 THICK)

Fig 9 : External Wall Section

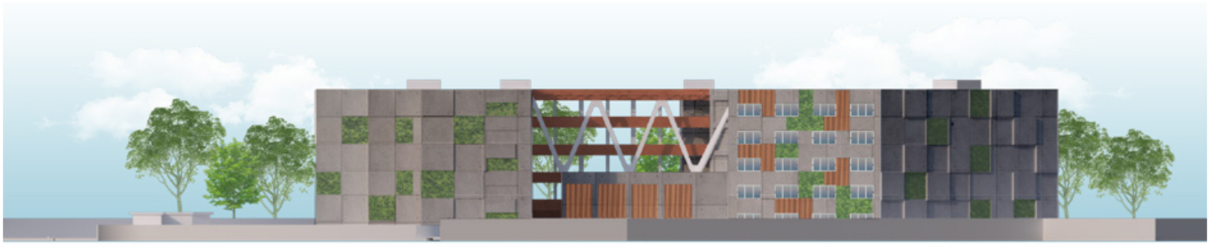


Fig 10 : NORTH - WEST ELEVATION

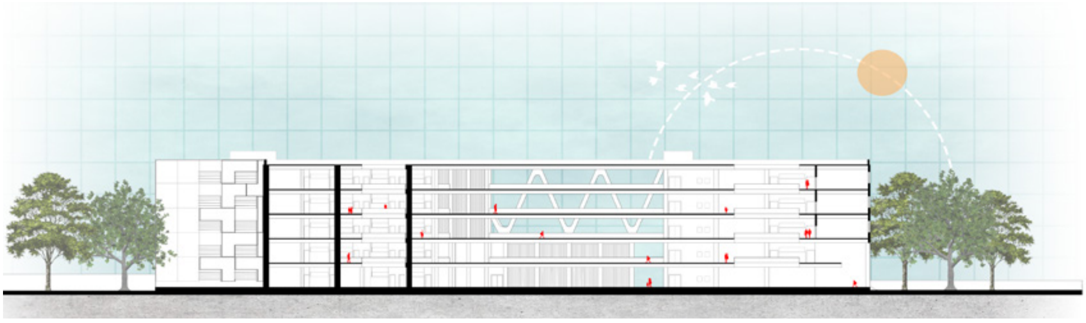


Fig 11 : NORTH SOUTH Section

Fig 12 : North Elevation

Fig 13 : North ENTRY


Fig 14 :


Fig 15 :

Energy optimization was approached as a step by step process. Using zoning, optimum orientation and courtyard effect we tried to reduce the cooling load on the building. In addition to that we have also optimized the envelope as well as maximized daylighting through passive strategies. The building was modeled in Design Builder with base-case values to get a comparison. Efficient active strategies like lighting and HVAC systems based on ASHRAE standards cater to thermal and visual comfort of the occupants. The efficient layout of solar panels on the roof area allows the building to generate electricity to fulfill its energy requirement.

Fig 16 :

ORIENTATION

- The building is divided into two blocks with one block having East to West axis, and the other block having North East to South West axis. Thus the heat gain is reduced by optimally orienting the shorter sides of each block towards South and South West direction.

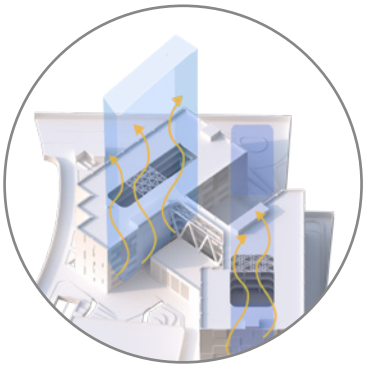


Fig 17 :

COURTYARD VENTILATION

- Each block has a courtyard to provide natural ventilation to the corridors and classrooms. Thus the cooling loads are reduced due to the mix mode thermal comfort model adopted to condition the spaces by the use of courtyards.

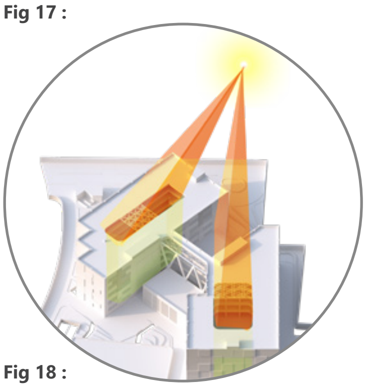


Fig 18 :

LIGHTING

- The courtyards in each block facilitated daylighting in the corridors and classrooms, which further reduced the requirement of artificial lighting and subsequently reduced the lighting loads of the building.

Fig 19 :

CROSS-VENTILATION

- The two blocks are bridged with overhead walkways to enrich the building with natural ventilation. The bridges aid cross ventilation and help maintain comfortable temperatures throughout the building.

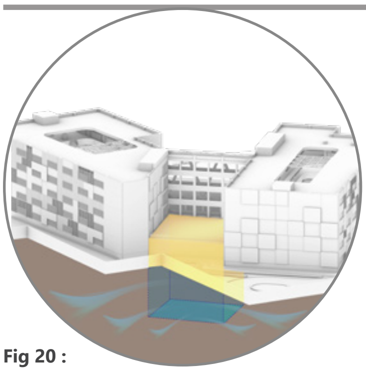


Fig 20 :

EARTH SHIELDING

- The multipurpose hall was sunk into the ground to incorporate the principle of earth shielding for the same. Due to the earth's heat sink property , the multipurpose hall is condiotned to comfortable temperatures without extensive cooling loads.

ENERGY MODELING PROCESS

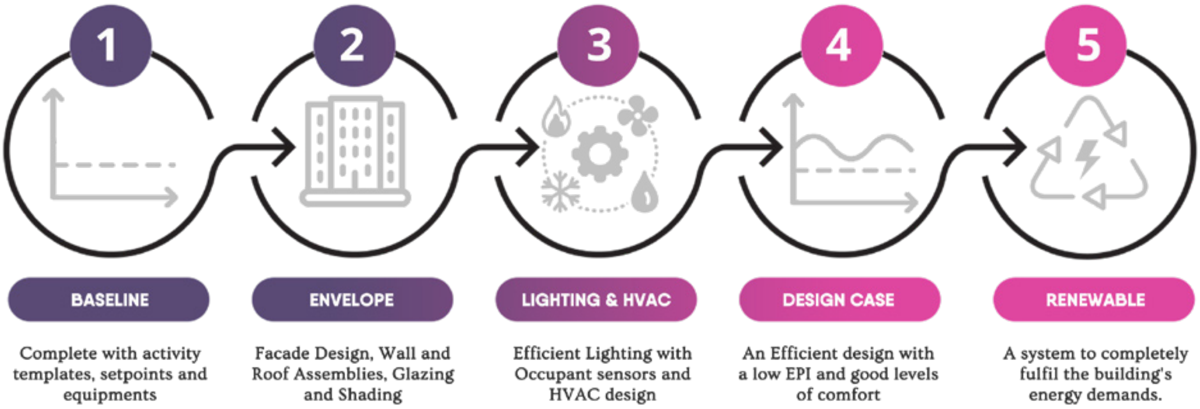


Fig 21 :

ENVELOPE OPTIMIZATION

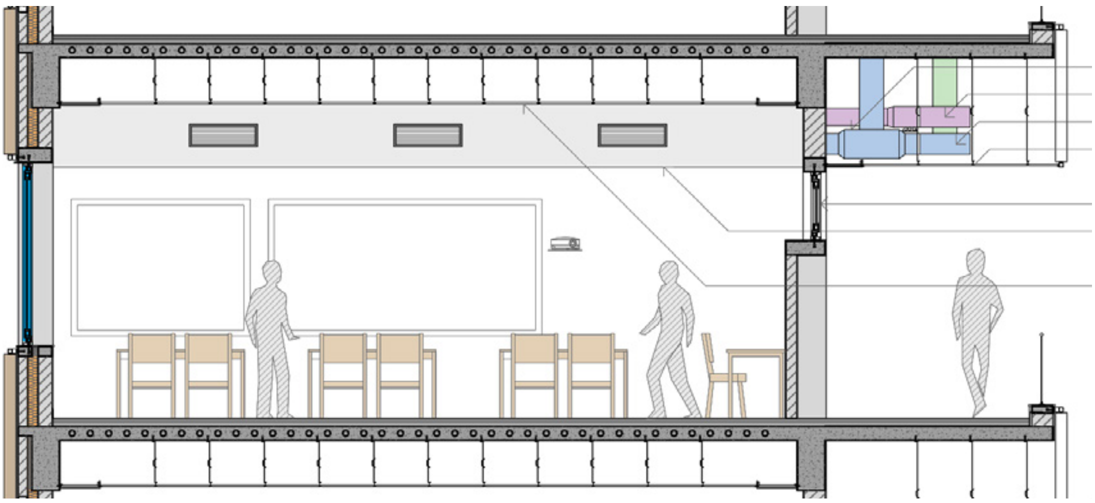


Fig 22 : Optimizing Envelope

- **BASELINE ENVELOPE**

  External Wall Assembly = 15 mm External Plaster + 230 mm Bricks + 12 mm Internal Plaster
  U-Value = 1.898 W/sqm-K
  Roof Assembly = 40 mm Brick tiles + 150 mm Cast Concrete + 6 mm ceiling plaster
  U-Value = 2.13 W/sqm-K

- **IMPROVED ENVELOPE**

  External Wall Assembly = 15 mm External Plaster + 75 mm AAC Block + 100 mm Cellulosic insulation + 150 mm AAC Block + 12 mm Internal Plaster
  U-Value = 0.210 W/sqm-K
  Roof Assembly = 40 mm Brick tiles + 180 mm Cellulosic Insulation +150 mm Cast Concrete + 6 mm ceiling plaster
  U-Value = 0.213 W/sqm-K

• FINAL ENERGY USES : BASELINE & IMPROVED

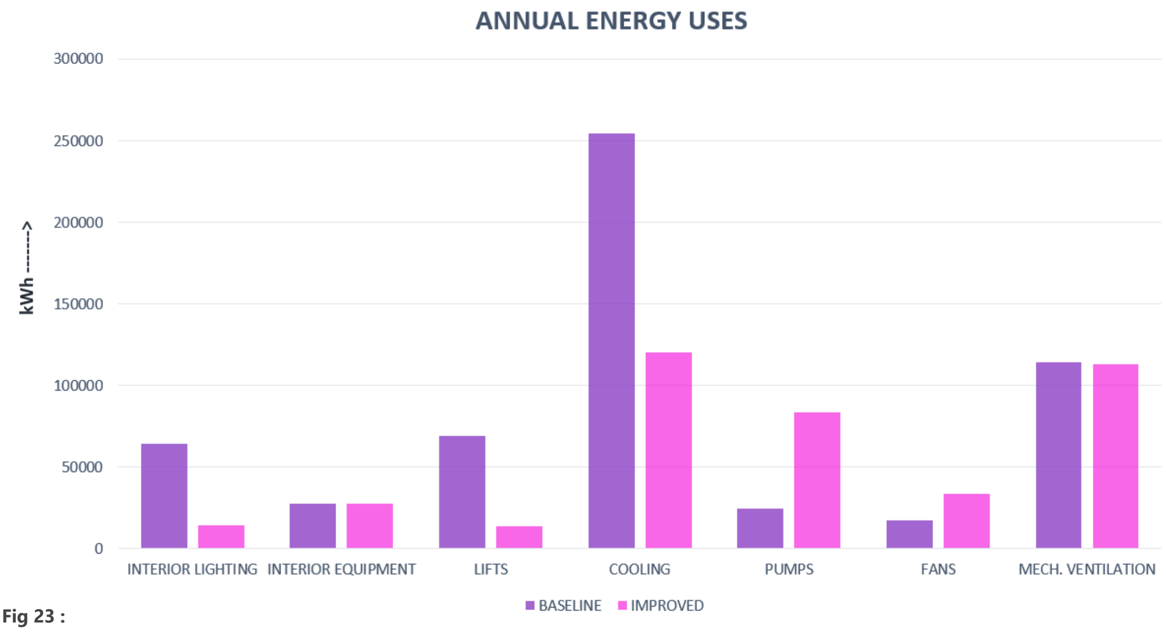


Fig 23 :

	BASELINE	IMPROVED	Percentage Change
	Annual Consumption (kWh)	Annual Consumption (kWh)	
Interior Lighting	**64366.5**	**14422.8**	**-77.59%**
Interior Equipment	**27549.93**	**27190.22**	0 (Practically)
Lifts	**68834**	**13845**	**-79.80%**
COOLING	**254596.8**	**120215.829**	**-52.78%**
Chiller_Radiant	-	63505.827	
Chiller_FCU	254596.8	52537.089	
Cooling_Tower	-	4172.913	
PUMPS	**24562.1**	**83729.95**	**240.89%**
Condeser Loop Pump	-	65019.84	
CHW_Radiant Pump	-	9712.16	
CHW_FCU_Pump	22942.1	7377.95	
Water Pumps	1620	1620	
FANS	**17156.98**	**33495.44**	**95.22%**
Fan Coil Units	17156.98	33495.44	
MECH. VENTILATION	**114410.92**	**113050.134**	0 (Practically)
AHU Supply Fan	57205.46	56525.067	
AHU Extract Fan	57205.46	56525.067	
Total Annual	**571477.23**	**405949.373**	**-28.96%**
EPI per conditioned area (kWh/sqm/yr)	65.08	**48.34**	
Total EPI (kWh/sqm/yr)	25.8	**18.33**	

TABLE 3

• RENEWABLE ENERGY GENERATION

Panel Used : LG Neon R LG380Q1C-V5
Size : 1,700 mm x 1,016 mm x 40 mm
Wattage : 380 W
Efficiency : 22%

LAYOUT:
The panels were arranged in long series, separated by circulation spaces of minimum 1200 mm in between them for maintenance and cleaning purposes. The panels were arranged in order to be clear from any big obstructions towards the south.

Due to the orientation of building blocks, the PV panels had to be titled in two different directions.

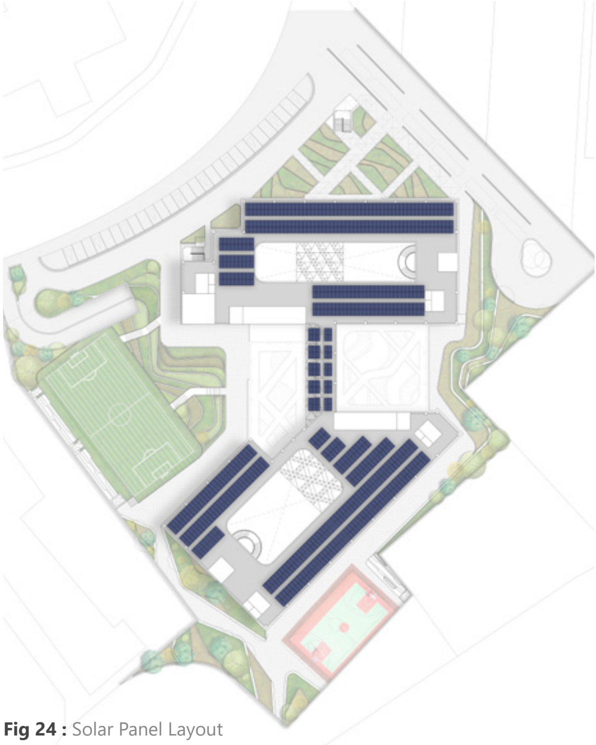


Fig 24 : Solar Panel Layout

SYSTEM 1 :
Azimuth = 180°
Tilt = 20°
Number of panels = 388
Wattage of one panel = 380W
System Size = 147.44 kW

SYSTEM 2 :
Azimuth = 135°
Tilt = 20°
Number of panels = 418
Wattage of one panel = 380W
System Size = 158.84 kW
Other Parameters entered in PV Watts (same for both systems) :
Module Type : Premium
Array Type : Fixed (roof mount)
System losses : 15%
Inverter Efficiency : 96%
DC to AC Ratio : 1.2

Total Energy Consumption in building in an year = 405949.373 kWh/yr
Energy Consumption EPI = 405949.373 / 22150 = 18.33 kWh/sqm/yr

Total Energy Generation in building in an year = 431659 kWh/yr
Energy Generation EPI = 431659 / 22150 = 19.49 kWh/sqm/yr

Net Energy usage = Energy Consumption - Energy Generation

Net Energy usage in an year = 405949.373 - 431659 = -25709.627 kWh/yr
Net EPI = 18.33 - 19.49 = -1.16 kWh/sqm/yr

So we have a surplus of around 25,709 units of electricity every year, thus making are building Net Positive.

	South Azimuth	South-East Azimuth	Total System
	Monthly Generation (kWh)	Monthly Generation (kWh)	Total Monthly Generation (kWh)
Jan	15213	14644	29857
Feb	16533	16242	32775
Mar	21173	21287	42460
Apr	21137	21756	42893
May	20442	21455	41897
Jun	17872	18864	36736
Jul	16692	17638	34330
Aug	17406	18358	35764
Sep	18630	19062	37692
Oct	18370	18222	36592
Nov	15780	15307	31087
Dec	15094	14482	29576
Total (kWh)	**214342**	**217317**	**431659**

TABLE 4

Electrical Properties (STC*)

Model		LG380Q1C-V5	LG375Q1C-V5	LG370Q1C-V5	LG365Q1C-V5
Maximum Power (Pmax)	[W]	380	375	370	365
MPP Voltage (Vmpp)	[V]	37.4	37.2	37.0	36.7
MPP Current (Impp)	[A]	10.17	10.09	10.01	9.95
Open Circuit Voltage (Voc, ±5%)	[V]	42.9	42.8	42.8	42.8
Short Circuit Current (Isc, ±5%)	[A]	10.84	10.83	10.82	10.80
Module Efficiency	[%]	22.0	21.7	21.4	21.1
Power Tolerance	[%]	0 ~ +3			

* STC (Standard Test Condition): Irradiance 1000 W/m², Cell Temperature 25 °C, AM 1.5,

** Measure Tolerance : ± 3%

TABLE 5

• GRID CONNECTION

Annual generation of electricity by solar panels is 431657 kWH. Out of that, energy consumption of electricity by the building is 405948 KwH. The energy generated by these panels go to a grid tie inverter to get converted to alternating current to get fed into the grid. Grid Tie Inverters are designed to quickly disconnect from the grid if the utility grid goes down. It ensures that in the event of a blackout, the grid tie inverter will shut down to prevent the energy it transfers from harming any line workers who are sent to fix the power grid. 165 kWh energy generated by the PV panels gets stored in 5 solar batteries of 33kWh capacity each(total 165kw) with inbuilt inverter, so that it can be used by the building during a power outage. From the Grid Tie Inverter, the alternating current goes to the ADCB (Alternative Current Distribution Box) Panel from where it gets directed to the grid supply.

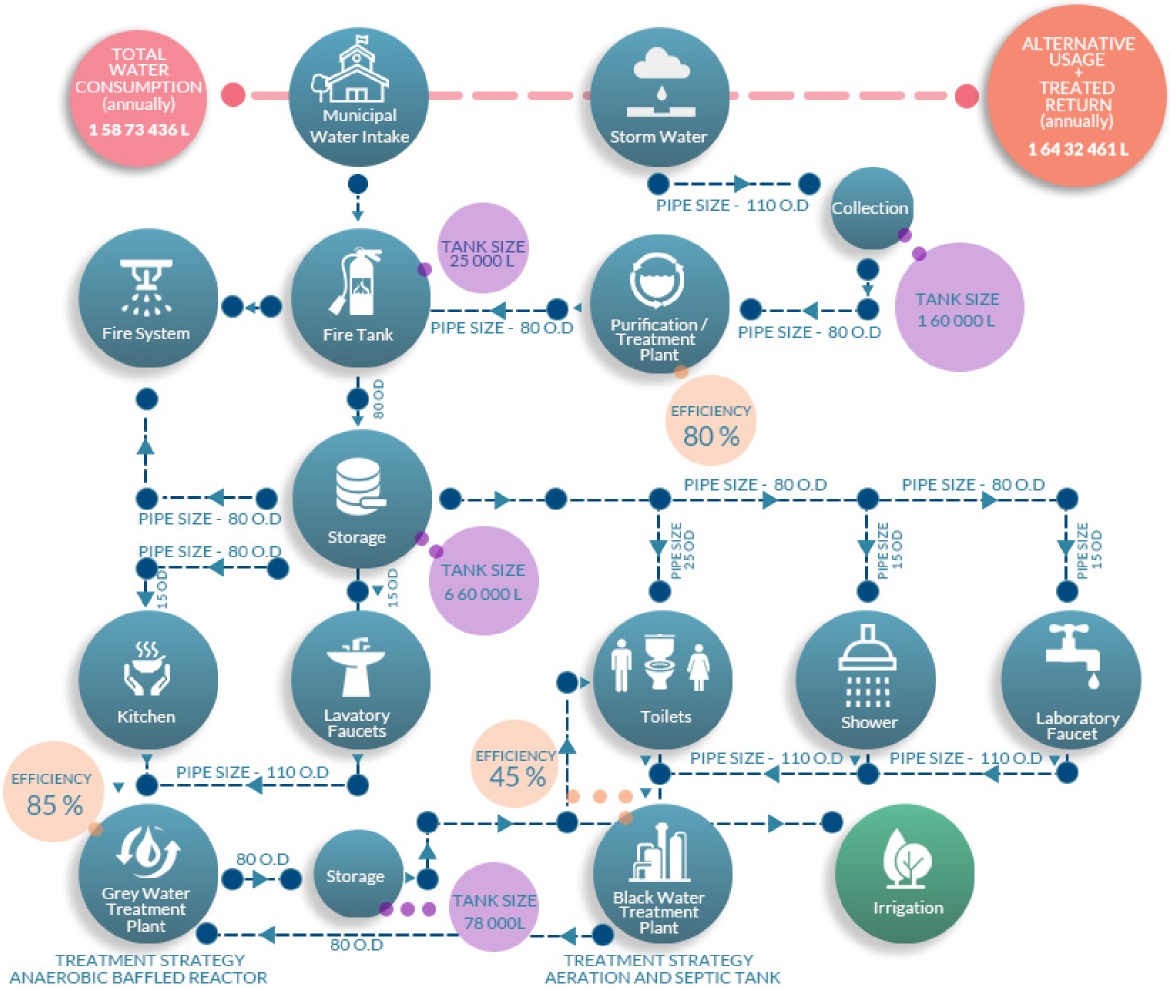


Fig 25 : Net-Positive Water Table Diagram

The presented annual water calculations suggest a comparison between a base case and a design case for the water cycle of the chosen building typology. Both the cases are multidisciplinary with respect to the basis and the assumptions made for estimating the amount of water consumed in the building for various purposes. The base case provides an overview on the consumption and requirement of water necessary for any school, by referring respective general conditions from standards such as the National Building Code of India and GRIHA Manuals etc. Here, the base case done at a preliminary design stage indicates an annual water consumption of 38815701L, where the school replenishes 32972678L of water through storm water harvesting and other waste water treatment strategies, leaving a difference of 5843023L between the demand and the provision. The design case however, accounts for a detailed consumption figures by considering efficient fixtures with downsized flow rates for the required for different facilities, incorporating effective strategies for landscaping like xeriscaping, which lets water seep into the bio-swales backed by surfaces convenient for entrapping most of the storm water for on-site harvesting and lastly selecting well regulated water treatment systems for meeting the water demands. Hence, as per the design case, the water cycle developed meets the annual water consumption requirements of 15873436L by recharging 16432461L of water, i.e. providing 559025L of extra water annually.

NOTES

- Refer Appendix : Sheet 41 for complete water calculation

- Treatment Plant

Black water, the water from the toilet WCS, urinals, shower drains and laboratory drains are treated in an areartion and separation tank. Aeration is the process of pumping air into a tank, this promotes microbial growth in the wastewater. The microbes feed on the organic material, forming flocks which can easily be settled out. After settling in a separate settling tank, bacteria forming the "activated sludge" flocs are continually recirculated back to the aeration basin to increase the rate of decomposition. After the biological flocs (the sludge blanket) settle, the clear treated water is then sent into an Anaerobic Baffled Reactor. An anaerobic baffled reactor (ABR) is an improved Septic Tank with a series of baffles under which the wastewater is forced to flow under and offer the baffles from the inlet to the outlet . The increased contact time with the active biomass results in improved treatment. Treatment performance of ABRs is in the range of 65% to 90% COD (Chemical Oxygen Demand) removal, corresponding to about 70% to 95% of BOD (Biological Oxygen Demand) (SASSE 1998; MOREL & DIENER 2006; BORDA 2008). This is far superior to that of a conventional septic tank (30 to 50 %, UNEP 2004). Here, we incorpate an ABR woth an efficiency of 85%. Now this treated water is then sent to all four 6500 L treated water storage tanks (overhead), water for the flushing of the WC and urinals.

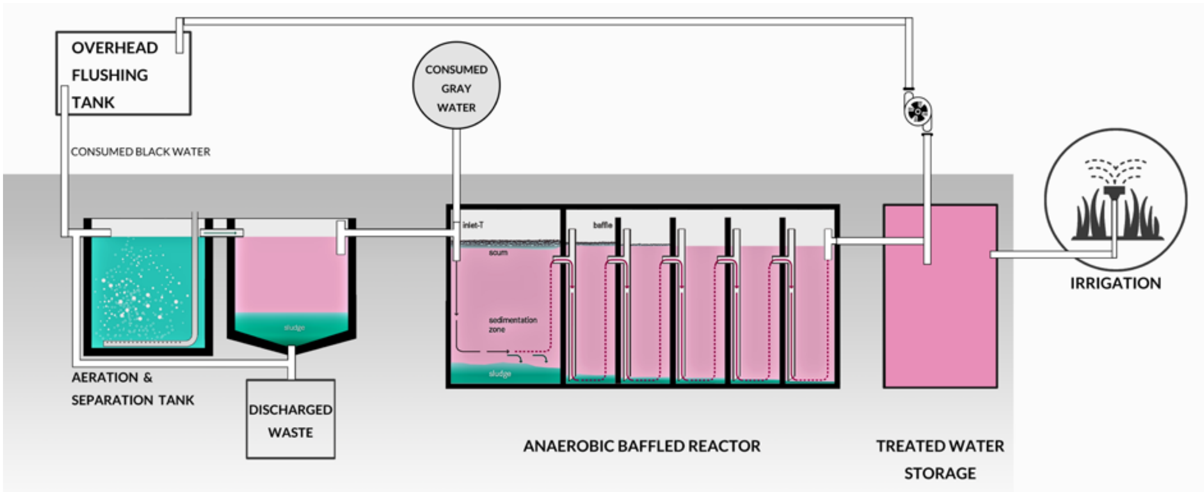


Fig 26 : Water Treatment Schematic Diagram

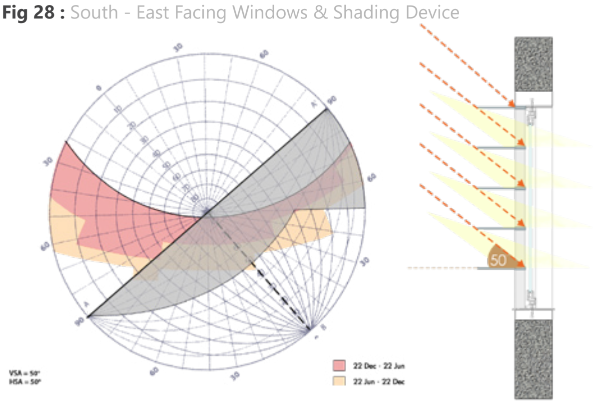
- Irrigation Schematic

The irrigation requirements for the institution are fulfilled by incorporating two systems of irrigation, viz. drip and furrow irrigation. The idea behind adopting these systems was meet the water demands of the greenscapes within the site without wasting much water. Drip irrigation provides and efficiency of about 95% which is used for water plants, bushes and smaller shrubbery. Furrow irrigation which offers about 80% efficiency and waters the larger trees on site, native to the respective region. Furthermore, the landscaping strategy of xeriscaping implemented helps in reducing the water consumption as well as wastage on site. The bioswales planned within the landscape carry the drained water through the storm water pipe which gets collected into the underground tank, treated by the filtration plant and then stored as white water to be used in the building for domestic purposes.

Fig 27 : Irrigation Schematic Diagram

Thermal and visual comfort highly depend upon the type of window systems and glazing that are being used in the building. These systems work in conjunction with other mechanical and active systems to provide a good experience in the working environment throughout the year.

Fig 28 : South - East Facing Windows & Shading Device



Window Opening | **Length** - 5300 mm | **Height** - 2000 mm
WWR - 40% | **Sill Height** - 900 mm | **Glazing Type :**
Super ECBC compliant

- SHGC : 0.25
- VLT : 0.46
- U value : 1.6 W/m²/K

Louvre Projection (south-east)

- 300 mm

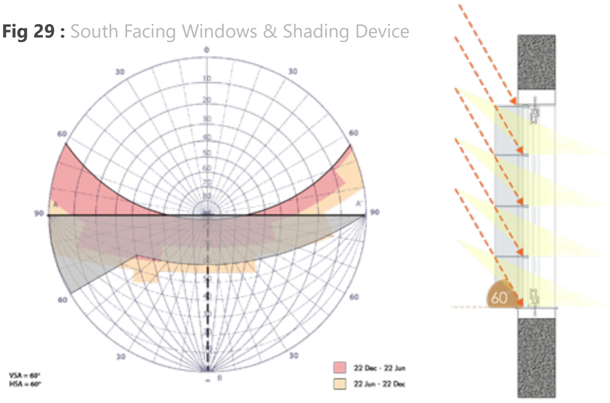
Louvre Count

- 5

Right Side Fin Projection

- 300 mm

Fig 29 : South Facing Windows & Shading Device



Window Opening | **Length** - 5300 mm | **Height** - 2000 mm
WWR - 40% | **Sill Height** - 900 mm | **Glazing Type :**
Super ECBC compliant

- SHGC : 0.25
- VLT : 0.46
- U value : 1.6 W/m²/K

Louvre Projection (south)

- 577 mm

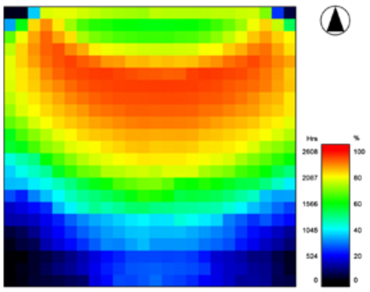
Louvre Count

- 2

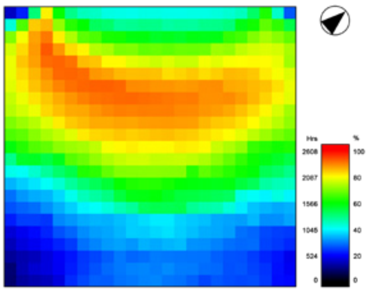
Side Fins Projection

- 615 mm

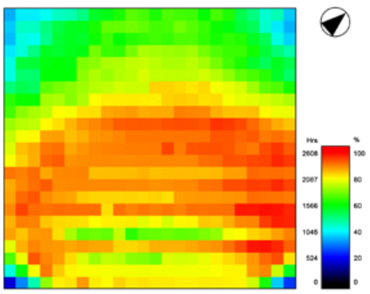
Fig 30 : UDI Maps For Typical Classrooms For Different Cases



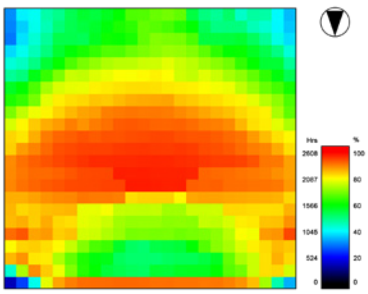
a) North facing classroom



b) North-west facing classroom



c) South east facing classroom



d) South facing classroom

- Lower luminance threshold : 300 lux
- Upper luminance threshold : 2000 lux

For achieving thermal comfort inside the classrooms, the first step was to optimize daylighting. For this, the window size and placement has been optimized in accordance with the working plane height, a special glazing type has been used for cutting the incident solar gains through windows. For classrooms facing South and South East, the specialized shading and glazing work together to cut down solar gain while balancing daylighting inside the classrooms. The classrooms facing North and North West however do not require the extra shading device as it would cut down daylighting even further. The UDI values have been optimized in accordance with the Super ECBC benchmarks.

NOTES

- Refer Appendix : Sheet 17 Shading Device Specification
- Refer Appendix : Sheet 36 - 40 for all UDI and SDA maps for all building floor plate

Comfort and Environmental Quality

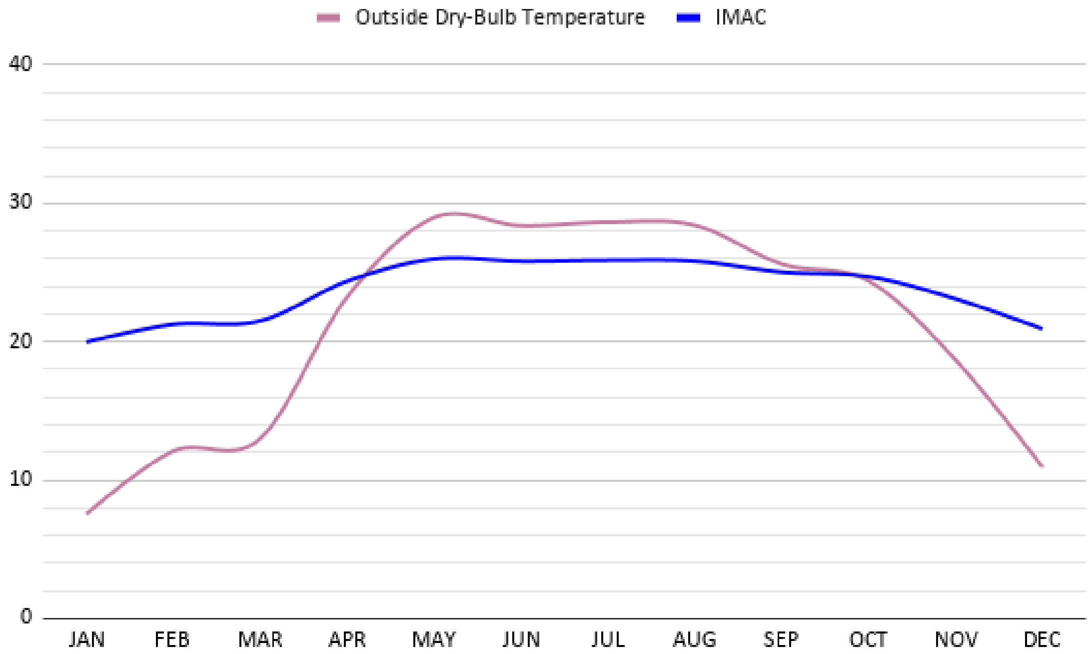


Fig 31 :

The building design is based on **IMAC Thermal Comfort Model** of the NBC.

The thermal comfort needs depend on occupants' context and varies with local outdoor environmental conditions. **Indoor Operative Temperature (IOT)** is the most suitable index, which accounts for the impact of the building surface temperature on human thermal comfort.

To calculate the IOT Index, the model was simulated for defining comfort strategy, and the temperature values were compared against the **Mixed-Mode Comfort Band** for identifying comfort hours.

IOT calculations are performed using the formula as demonstrated:
Indoor Operative Temperature = (0.28 x Outdoor Temperature) + 17.87

Here, IOT (°C) is the neutral temperature, while outdoor temperature is the 30-day outdoor running mean air temperature (°C). The 90 percent acceptability range for the India specific adaptive models for mixedmode buildings is ±3.46°C of the IOT. Comfort conditions were also established after considering humidity;

90% humidity threshold was considered with the comfort band and the IOT values were attained from the simulation.

Without HVAC

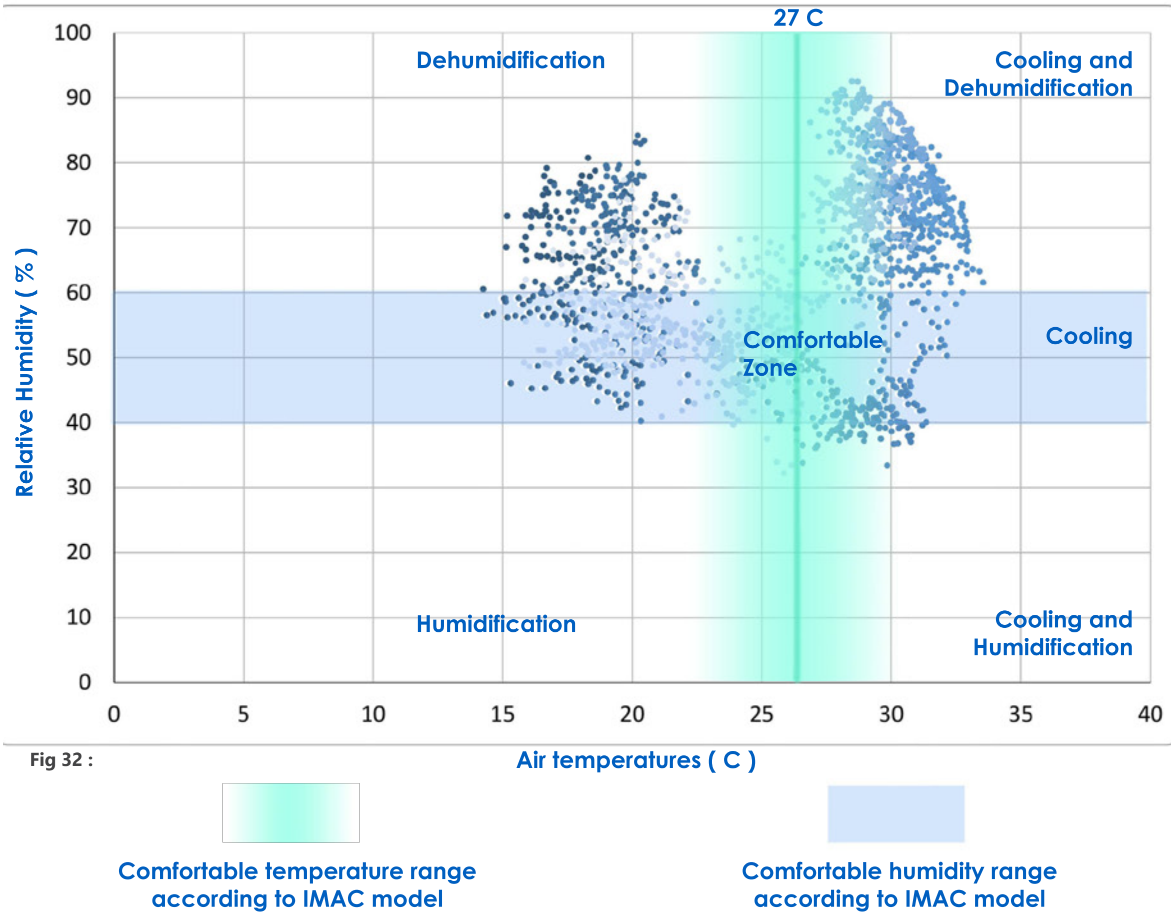


Fig 32 :

With HVAC

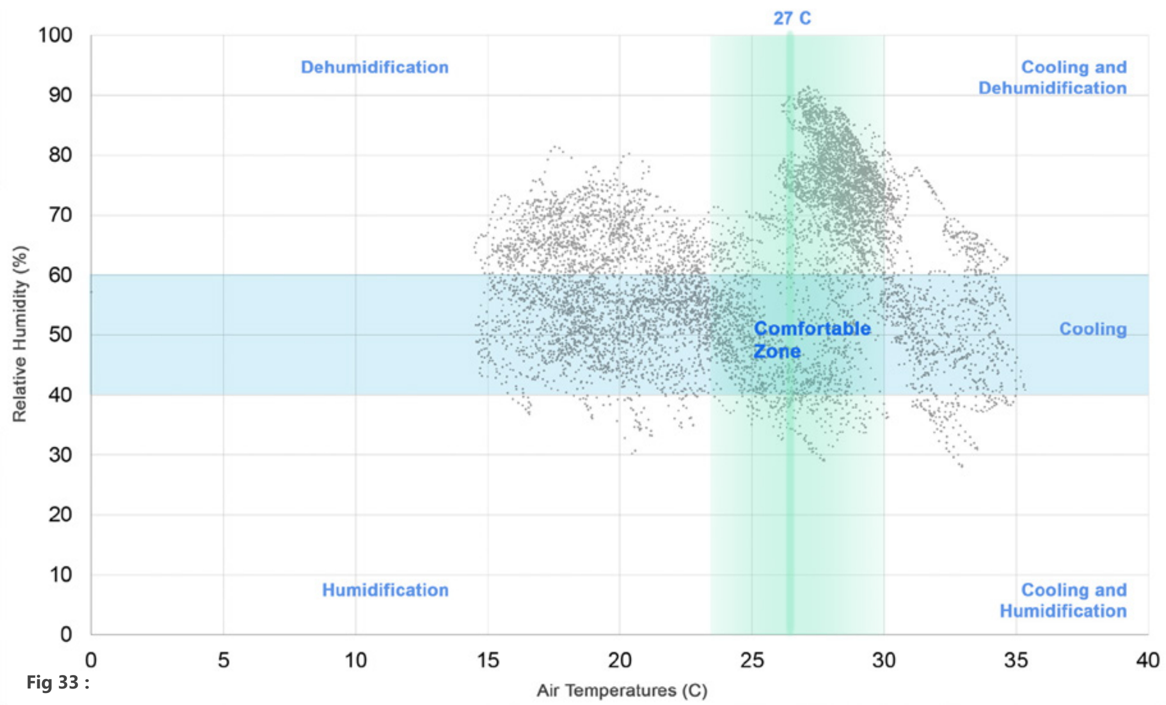


Fig 33 :

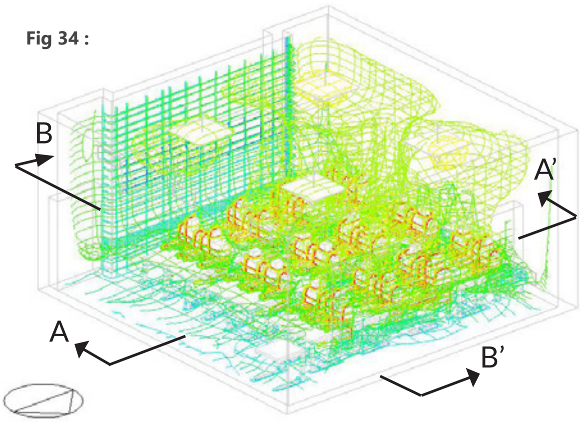
Hourly thermal analysis done on the design with and without HVAC to understand indoor environmental conditions. Indoor RH against air temperature have been plotted.

The air velocity, pressure, and temperatures in the zones were monitored through CFD analyses. The outside air quality of Delhi is poor, and in the scenario of the ongoing pandemic, it was very important to achieve an environment where students productivity and health were facilitated in a clean, healthy, and safe indoor environment. We optimised the indoor conditions to meet high standards of comfort and air quality to achieve this state.

We tried various ducting layout iterations with the goal of achieving efficient air changes in the zones. In the classrooms, we maintain 6.5 ACH, meeting and exceeding ASHRAEE's standards for the same. All the spaces were monitored carefully based on occupancy and have been scheduled for the ACH required.

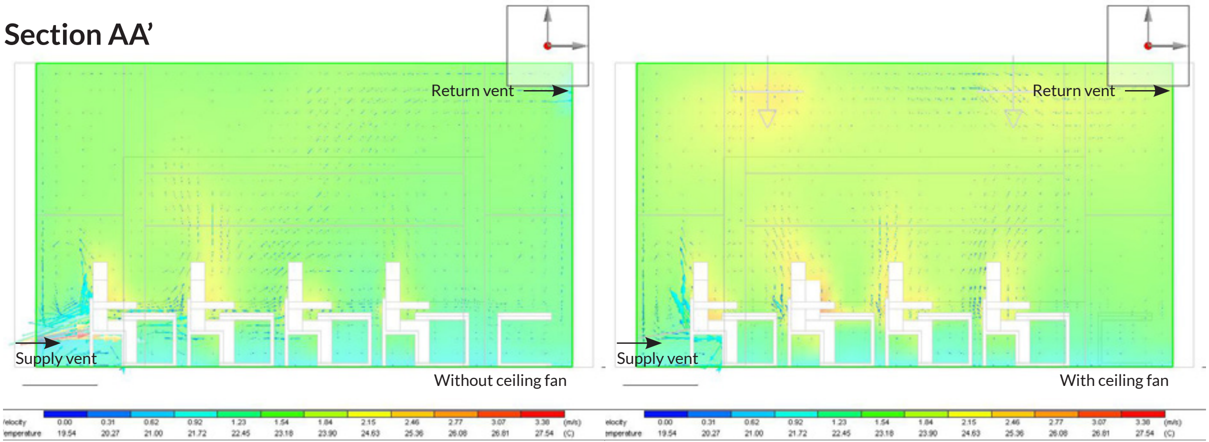
Air is filtered using HEPA filters in the AHU, and further exposed to an UVGI unit to kill microbial presence. The flow rates and exposure times have been set to achieve an efficiency of 60.6%. (FORM: 102.20-AG16 (908)

Fig 34 :



The objective was to move the air breathed out, away from the occupants, before it recirculated back to them. This was achieved by tilting the diffuser air throw slightly. The duct comes from the lower level of the wall, and each diffuser throws the air at a rate of 115 L/s, at a speed of 2.5 m/s. Further, the exhaust vents are placed at the upper level of the opposite wall, so that the return air is drawn out and picked up and exhausted out. This was achieved after multiple iterations.

Section AA'



Section BB'

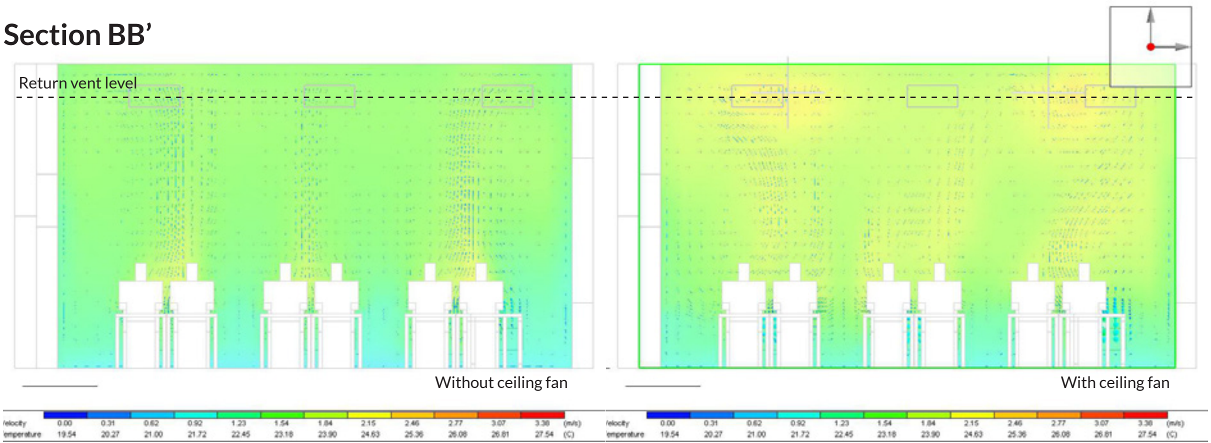
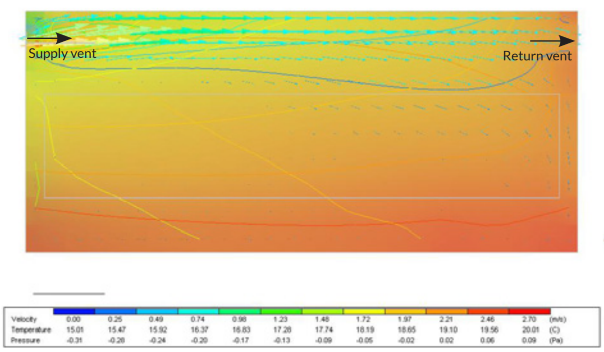
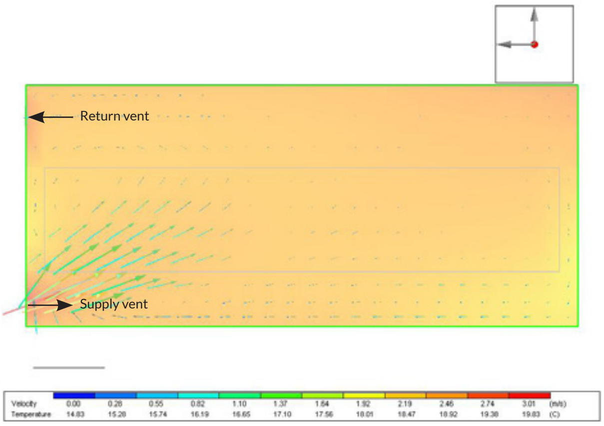


Fig 35 :

Fig 36 :





Iteration-1 : Vents at upper level; opposite walls ***(Discarded)***

Iteration-2 : Vents at upper & lower level; same wall ***(Discarded)***

Fan sizings and placements were derived after looking at a study showing effects of air speed directions, and horizontal distance from fan center. Using this data, fans and the HVAC system in majority of occupational hours, is able to achieve thermal comfort using natural ventilation, reducing the cooling load on the building.

The intake of the FAHU is taken from the courtyard, due to its better air quality, while the exhaust is done to the outside of the built form.

In the FAHU, we have a heat-plate recovery, of efficiency 0.65 to 0.7, in order to capture the sensible heat, and not latent, to better enhance air quality.

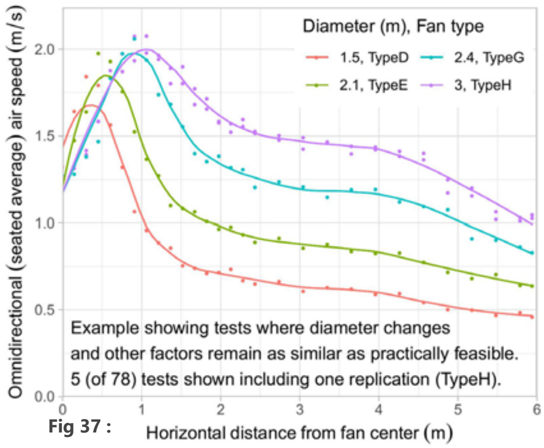
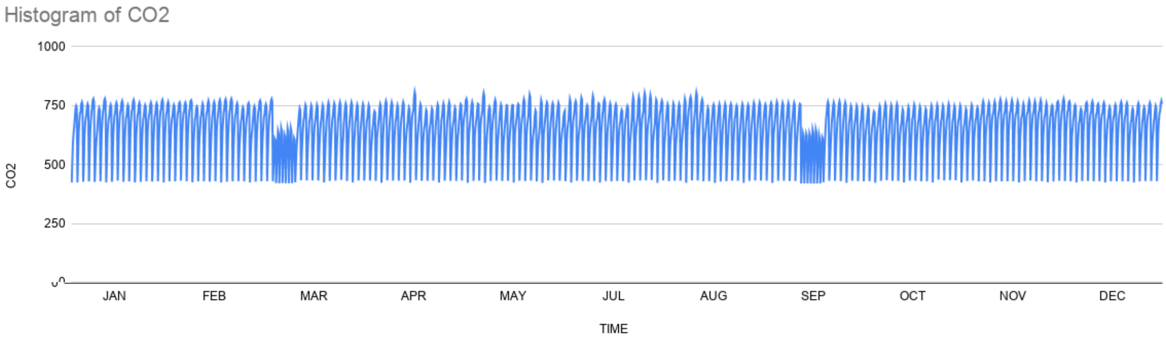


Fig 37 :

Fig 38 :



The above graph represents the average of CO_2 levels of all the zone groups in the school. The levels are maintained below 1000 ppm in schools as per ASHRAEE.

HVAC

Conditioned Area = 8,297 m2
Total Mechanically Ventilated Area = 12,330 m2
Total Cooling Load = 460 TR
Total Sensible Load = 178 TR
Total Latent Load = 282 TR
Proposed HVAC System : Chilled Water System with Fan Coil Unit + Radiant Floor Cooling
Air Distribution System : Fresh Air Handling Unit (FAHU)

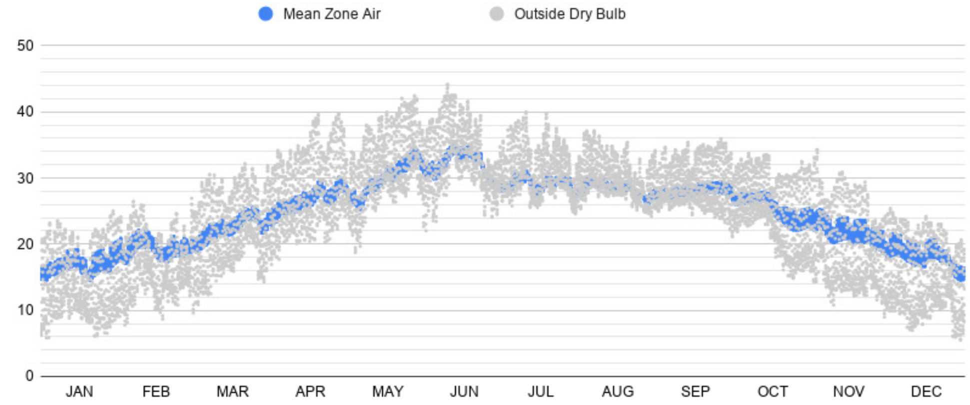


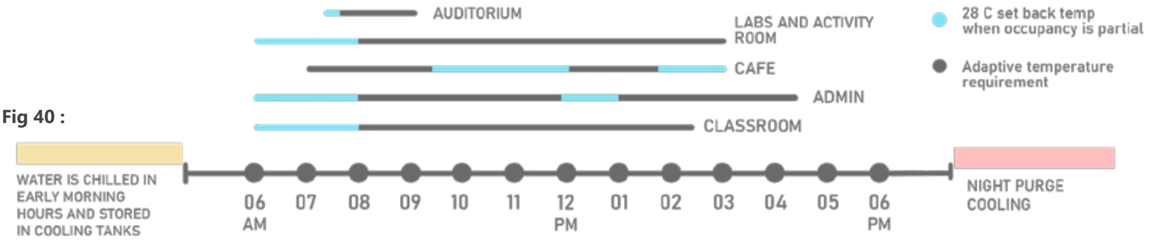
Fig 39 :

Strategies for Efficient System Operation:

- **Night-Purge Ventilation** by keeping windows open at night to flush out warm air and cool the thermal mass for the next day, taking advantage of courtyard micro-climate.
- **Pre-Cooled Spaces** by running the chillers at early morning hours in cold outside temperatures, cooling down the liquid water and storing it in the cold storage tanks to be used during operational hours. Two hours prior to the school timing (from 6am-8am), the system is set to a setback temperature of 28°C, easing the temperature transitions.
- **Operation Scheduling & Specific Space Zones** based on activity and space usage for the HVAC system, which can be controlled in the individual zones, and can later be managed as per the timetable schedule for efficient system operation by BMS.
- **Sensible Heat Recovery** is achieved through having a heat recovery wheel in FAHUs which are provided in each zone, further controlled by BMS. This **recovers 60% of the sensible heat**, which is pumped back into the rooms. Furthermore, air dampeners are provided to reduce airflow to spaces which are not in use.
- **Recapturing water from dehumidified air** for cooling, as it is pre-cooled air.

The multi-purpose hall is ventilated via an UFAD System dude to it's large head height, and it is cooled via the chilled water system. Whereas, the swimming pool is ventilated through an AHU, to maintain an air temperature that is around 2 degrees above water temperature.

Fig 40 :



The HVAC system scheduling was determined by the simulation software by making the cooling available 2 hours prior to the school starting, and the setpoint temperature is fixed to 26 degee Celcius, and the system was autosized by the simulation software.

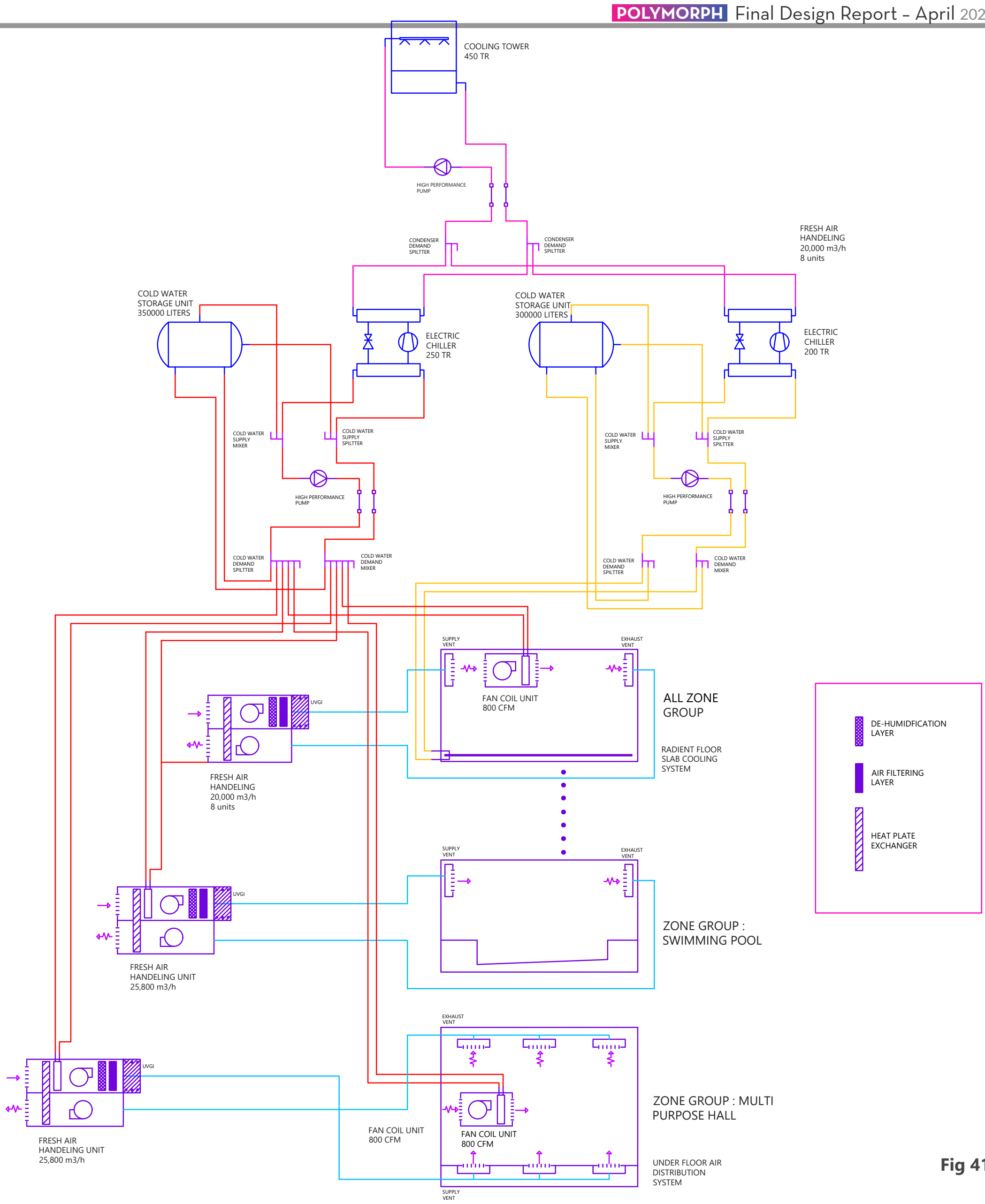


Fig 41 :

The HVAC system of the building consists primarily of a radiant floor cooling system, coupled with a chilled water cooling system, for cooling. For ventilation, a Fresh Air Handling Unit has been provided (FAHU). Ceiling fans have also been provided in all the conditioned rooms. The goal is to reduce the HVAC system operational hours by maximising natural ventilation with ceiling fans. By means of Building Management System (BMS), the radiant cooling would be used as the primary conditioning system, while chilled water system would be used only when there is an additional cooling requirement to meet the comfort hours. This coupling reduces the chilled water system cooling load by about 60%. Large courtyard spaces have been designed which help in facilitating natural ventilation and create a micro-climate, from where the FAHU draws fresh air. Two chillers have been provided in the basement to meet the different cold water temperature requirements of the two cooling systems (chilled water system - 7 C, radiant cooling - 14 C), which are further connected to a cooling tower placed on the terrace. Each chller has its own cold storage tank to operate at early morning hours, to increase efficiency. The multi-purpose hall is conditioned using an Under Floor Air Distribution (UFAD) system for fresh air distribution, and the chilled water system for cooling. Whereas, the swimming pool is ventilated using an AHU. Furthermore, the AHUs are equipped with Ultraviolet Germicidal Irradiation (UVGI) units to ensure that microbial and viral presence are minimised in the air.

TABLE 6

Equipment	Location	Sizing	Product	Source
Fan Coil Unit	1 per classroom	800 cfm	DAIKIN THINLINE HORIZONTAL	https://oslo.daikinapplied.com/api/daikindocument/DownloadDocumentByName/Doc100/ThinLine%20Horizontal%20Fan%20Coil%20Catalog%20Daikin%20CAT%20724-10%20LR.pdf/
Exhaust Diffusers	3 per classroom	700 x 250 mm	TITUS FL-20	https://www.titus-hvac.com/Products/Diffusers
Supply Diffusers	3 per classroom	700 x 250 mm	TITUS FL-20	https://www.titus-hvac.com/Products/Diffusers
UVGI Unit : Airborne Inactivation Option	1 per AHU	1kW	YORK UV-C	https://www.johnsoncontrols.com/-/media/jci/be/united-states/airside-systems/air-handling-units/files/be_appguide_uvclight_ahu.pdf?la=en&hash=4FC07C3AD214C1E148C8DC0DF82855E2E22178E1
AHUs	2 per floor (8 units, 4 floors); 2 units basement (for multi-purpose hall and swimming pool)	20,000 m3/hr (8 units), 25,800 m3/hr (2 units)	DAIKIN MODULAR R	https://www.daikinmea.com/content/dam/document-library/catalogues/as/air-handling-application/Air%20handling%20units_Product%20catalogue_ECPEN18-810_English.pdf
Water-Cooled Chiller	2 in basement	250 TR, 200 TR (COP 6.2 (IPLV 10.7))	LG OIL-FREE AIR-BEARING CENTRIFUGAL CHILLER	https://www.lg.com/global/business/download/resources/sac/Leaflet_F_LG_Centrifugal_Chiller.pdf
Radiant Cooling PEX Pipes	laid in select zones	varies as per zone	PEX PIPES	https://www.kailashtubes.com/viega-pexpipes/
Ductworks	-	varies with length	DAIKIN ALU DUCTWORK	-
Dampers	at split junctions	-	JOHNSON CONTROLS RC-200	https://www.johnsoncontrols.com/hvac-equipment/air-distribution/dampers-and-louvers/dampers/rc-2000
Cooling Tower	1 on terrace	450 TR	PROTECH PSC-SERIES	http://protechcoolingtowers.com/square_shape_cooling_towers.html#
Chilled Water Piping	-	-	-	-

The sizing for equipments were based on simulation data, loads, and market availability.

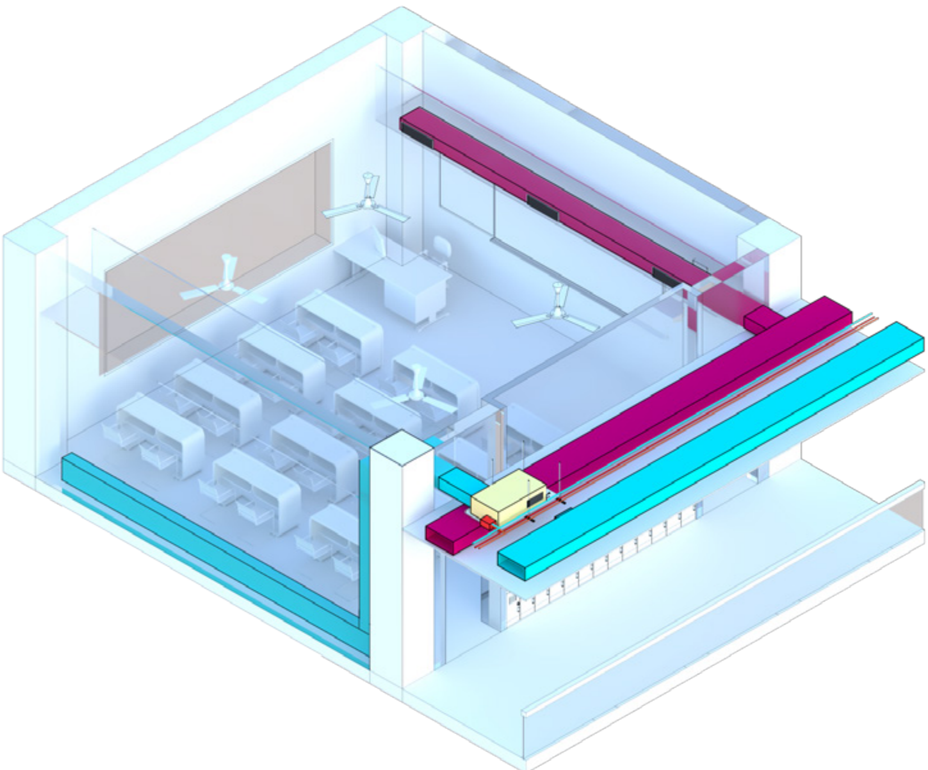


Fig 42 :

The system has been layout after testing out CFD variations in air pressure, velocity, and temperatures. The final desirable conditions were achieved by laying the fresh air supply diffusers on the lower end of the wall in the zones, with the return air diffuser on the upper end of the opposite wall. The fresh air supply duct provides chilled air to the fan coil unit for cooling the zones. Furthermore, ceiling fans have also been provided in the classroom to aid in air circulation, as well as to help achieve thermal comfort with natural ventilation.

• Risk Analysis

From disaster management aspect, the industrial nature of Noida has to be studied carefully for possible hazards in the form of natural disasters such as earthquakes, floods and high winds as well as manmade disasters such as fire,ndustrial accidents etc. Risks to the site include:

Flood Risk : Noida was part of the river basins of Yamuna and Hindon which were reclaimed for development by constructing embankment. It is the low lying and likely to face large scale flooding if the embankments along the rivers get breached.

Earthquake Risk: Noida falls in seismic zone IV and shares common boundaries with vulnerable states like Delhi, Haryana.

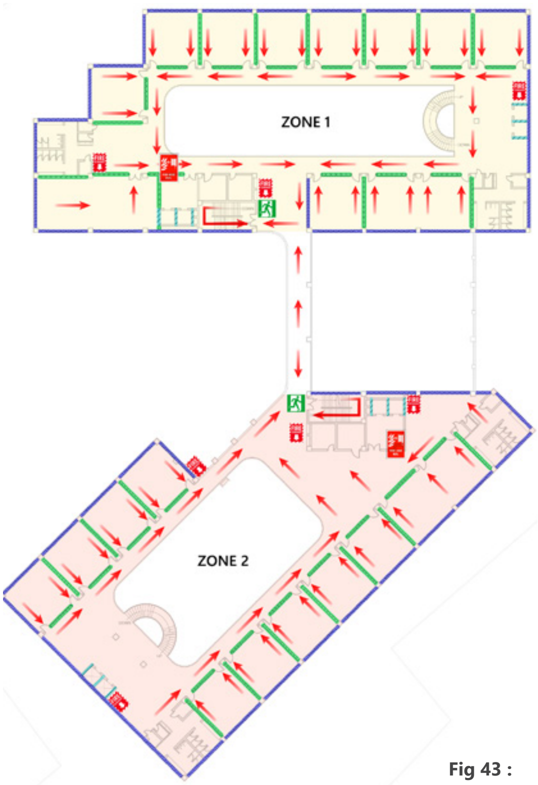
Man Made Risks: There are many possibilities of manmade disasters occurring in the area due to pollution, road accidents or fire.

• Passive Performance

The building mass is designed around 2 major courtyards which are semi covered on top. These courtyards have trees planted and appropriate landscaping which create a microclimate inside the building which brings in good ventilation throughout the building. Windows along every facade have been shaded with specifically designed shading which brings in comfortable daylight throughout the day. The central spine of the building helps in creating good airflow between the two building blocks. Clear low E glass-Air gap-Clear Glass has been used in windows to thermally insulate the classroom and prevent the cool air from escaping. The facade of the building is designed to complement the passive strategies integrated into the building. Materials including terracotta, cement fibre boards and green planter panels have been used each of which has their benefits and properties. Terracotta is a self cleaning, recyclable material that cools the air. Green planter panels with hardy plants like ferns and moss can absorb CO_2 and pollutants and clean surrounding air.

• Fire Resilience

To make the building more resilient to fire, fire Norms according to NBC part IV guidelines have been followed. Water sprinklers have been provided at appropriate distances. There is a large egress point above the multi-purpose point which acts as an intermediate waiting point for people to collect in case of fire and then be rescued. The central spine in the building allows for fresh air to be brought into the atrium. A detailed evacuation plan has been drawn and will be placed at every floor. In case of an emergency, arrows pointing to the nearest fire exit can be followed through signage on the walls. Fire extinguishers at regular intervals are placed. Safety protocols to be followed will be taught to the students as part of fire safety training.



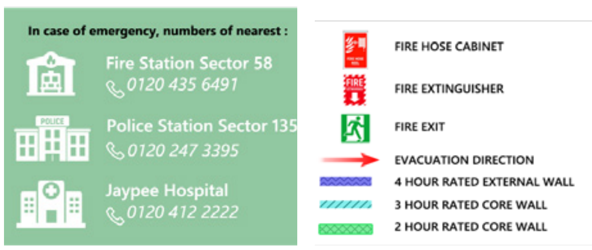


Fig 43 :

Evacuation Plan for Typical FLoor Plan

NOTES

- Refer Appendix : Sheet 28- 29 for Sprinkler and Smoke Dectector Layout

• Flood Resilience

Drainage systems have been designed according to local design standards. Issues such as discharge of floodwater from the hardscapes, back-flow prevention, screening of discharge points to prevent debris blockage, etc. are to be considered during the planning stage. Bioswales and Discharge gutters have been created at appropriate locations to collect stormwater run-off. Water pumps have been provided at the lowest point on the site to drain water from the site. Rain water storage tank of capacity 172000L has been provided on-site. Grey and black water harvesting tank capacity 200000L has also been provided.

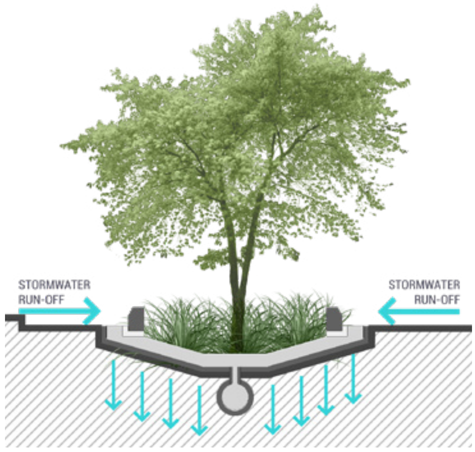


Fig 44 : Bioswales

• Energy Sufficiency

• Energy Sufficiency

Renewable energy generation from solar panels has been used to generate electricity on-site. The overall energy requirements of the building has been lowered by reducing cooling loads. Passive cooling strategies like the courtyard effect, shading design based on solar angles, using planters on facades have been used to lower cooling loads of the building. Active strategies involve using a centralised Chilled Water System with Radiant Floor to distribute cool air along conditioned spaces. The PV panels generate 431657 kWh. Part of that energy generated gets stored in 5 solar batteries of 33kWh capacity each(total 165kw. Incase of emergencies such as earthquakes or floods, the building emergency protocol would allow only essential appliances to work. Average energy consumption of the building for 6 hours is 159kWh. In this kind of situation the building can still operate for about 3 hr

• Water Sufficiency

The capacity of the white water tank has been decided based on daily domestic consumption of 68490L/day. Grey water generated is 27,000 L/day whwreas the black water generated is 41,490L/day. There are four white water overhead tanks have a capacity of 30,000L each and is sufficient to last for 2 days; and the underground white water tank has a capacity of 6,60,000L sufficient to last for 3 more days in case of a water cut. The four overhead treated grey water tanks have a capacity of 6500L whereas the underground treated grey water tanks tank has a capacity of 78000L and can cater to the flushing requirements for 2 and 3 days respectively.

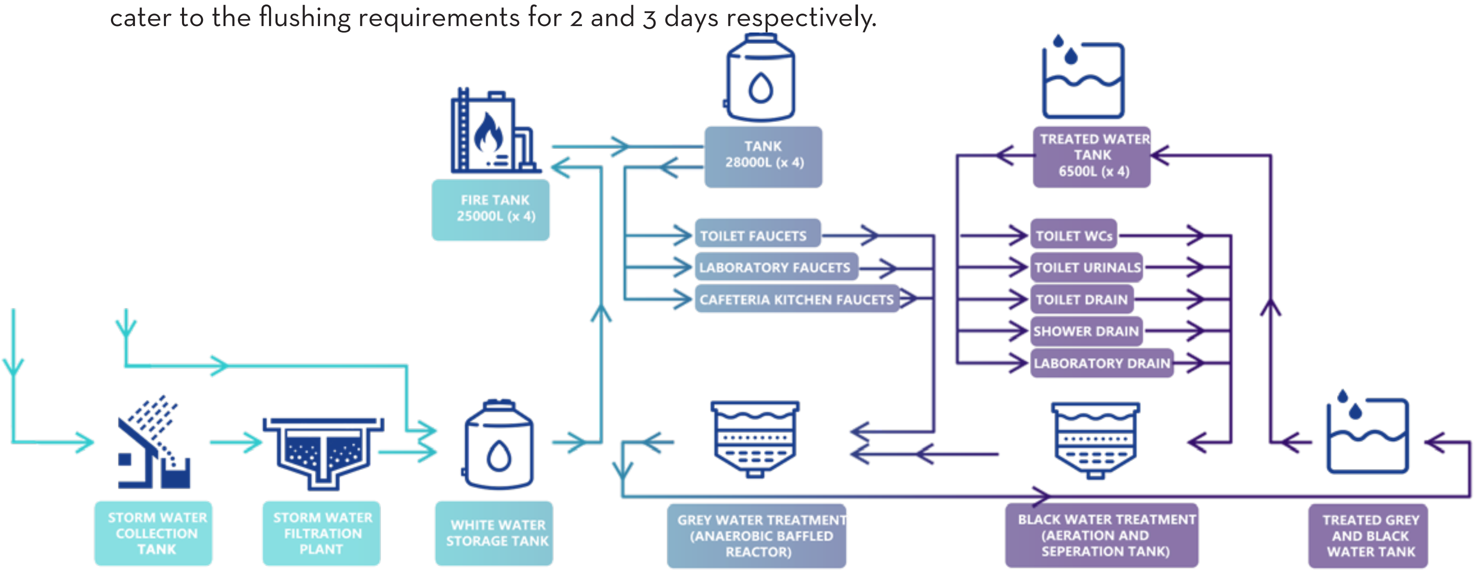


Fig 45 :

Schematic Water Resilience Chart

- ## Resilience to Public Health Hazards

In recent times, schools need to adapt to the possibility of functioning during pandemics. We propose a multi- layered plan in accordance with the government issued guidelines to reduce exposure and limit transmission between students. As per ASHRAE, relative humidity is maintained between 40% and 60% to help reduce COVID-19 infection rates. While positive impacts of humidification on COVID-19 have not been determined, avoiding dry conditions in buildings is generally thought to be effective as a risk reduction strategy in buildings. Ultraviolet Germicidal Irradiation (UVGI) will be incorporated into supply air ducts of the Air conditioning system to destroy airborne viruses present in recirculated air. Indoor air recirculation will be avoided or minimized as much as possible. Minimum 6 air changes per hour (ACH) of clean air as per guidelines. Increasing indoor airflow rates, without increased outside air delivery can potentially increase transmission, as it could escalate exposure to viral aerosols exhaled from other infected occupants. Installing touch less technology for dispensers of hand soap, hand sanitizer, and paper towels to limit transmission, water fountains operated by foot pedals. Staggered school arrival and departure times, class transitions, and locker access so that children in different classes won't enter or exit the building at the same time. Even a difference of 5-10 minutes for each class or grade level could greatly reduce the number of students in the hallway heading to the door for dismissal at one time. Managing airflow between zones through pressure differentials is a common practice in healthcare settings. Areas like nurse's office, isolation rooms, and washroom cores would be negatively pressurized.

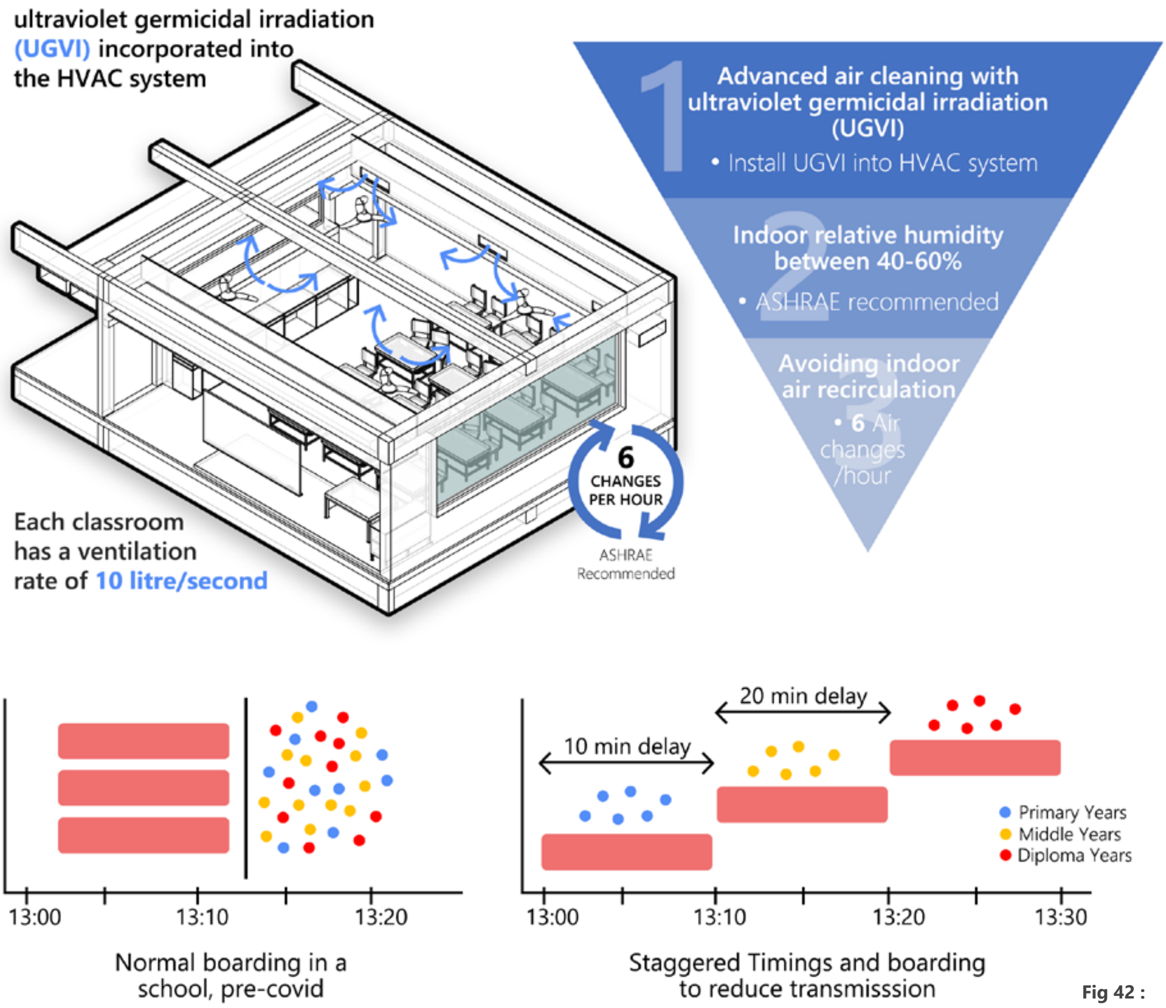


Fig 42 :

Fig 46 : COVID Resiliency Strategy

- ## Project Summary

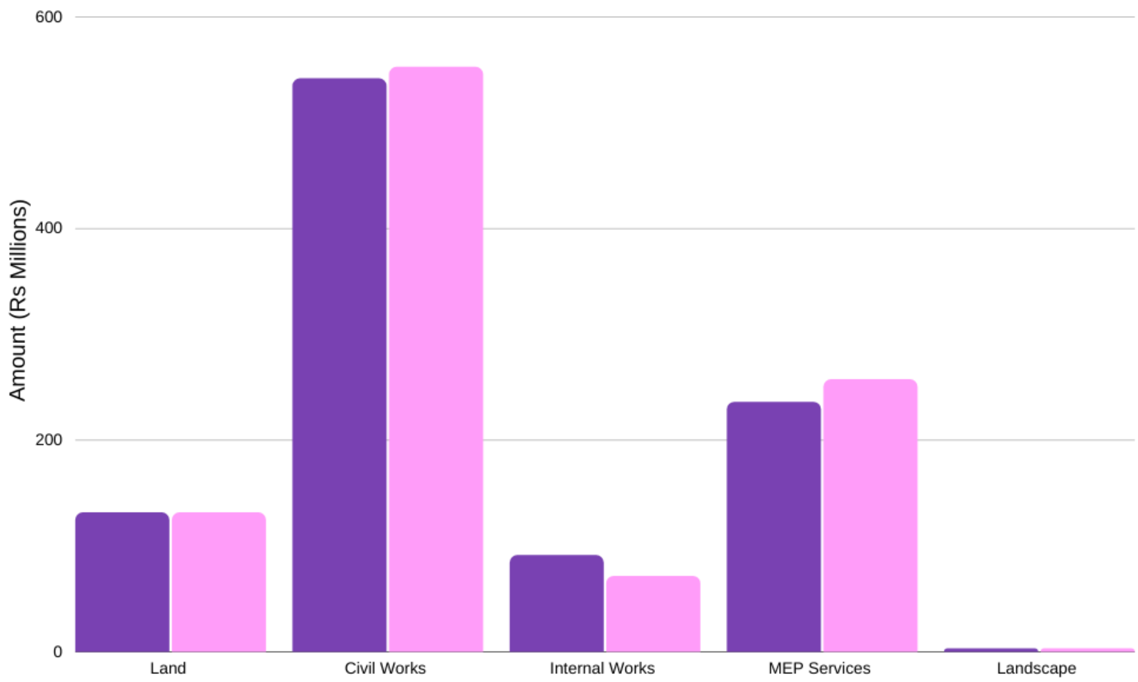


Fig 47 : Project Summary

A detailed bill of quantities was made utilizing the Schedule of rates and expert consultation. We compared our proposed design with a base case. The total project cost of the base case was determined to be ₹1047.15 Million and that of the proposed design was determined to be ₹1073.76 Million, which is only 2.4% more expensive than the base case. This is achieved through various design strategies to reduce the cost.

- ## Design Strategy to reduce cost

- ### HVAC

The cooling loads of the building have been brought down by both the low e value glass and a more efficient building envelope. This in turn reduces the cooling loads of the HVAC system; so although the Radiant Cooling + Chilled water system is more expensive than the VRF, the cooling load is reduced which then brings down the cost of the HVAC system to 36 million from the 44.1 Million VRF system.

- ### WATER

Water is saved by using efficient fixtures, which then reduces the water demand and thus the overhead tank has become smaller in size. To support the resilience of the building we have increased the size of the underground tank.

- ### ELECTRICAL

The solar panels generate enough electricity for the building to be net positive, which allows us to sell the power outside. The electrical appliances are energy efficient,which are generally costlier, but this in turn reduced our energy demand.

- ### FLOORING

Screed flooring is used to further reduce the cost of the building

The solar PV panels give us 78.15% in savings in 20 years as opposed to using electricity from the grid. The solar panel has a payback period of 3.17 years when considering the savings from annual electricity bills.

The chilled water and radiant cooling system comes up to 18% in savings in 20 years when compared to a VRF system. Hence according to the life cycle costing of the system it is concluded that the proposed design is cheaper than a VRF system. Owing to the reduced cooling loads resulting from a more efficient building envelope, the CAPEX of the proposed design is also reduced.

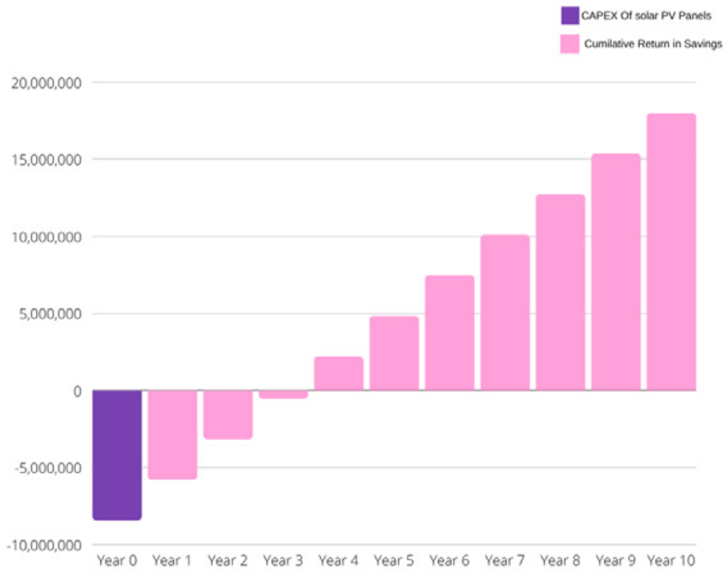


Fig 48 : Life Cycle cost of PV Panels

Life Cycle Cost - HVAC System			
YEAR	**COST COMPONENTS**	**Base Case (VRF)**	**Proposed Design (Radiant Cooling System+ Chilled Water System)**
0	CAPEX	₹ 4,41,10,000	₹ 3,60,00,000
1	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
2	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
3	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
4	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
5	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
6	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
7	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
8	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
9	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
10	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
11	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
12	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
13	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
14	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
15	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
16	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
17	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
18	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
19	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
20	Opex + Repair and Maintenance	₹ 4,700	₹ 2,200
Total Life cycle cost in 20 years		**₹ 4,42,04,000**	**₹ 3,60,44,000**

Total savings in 20 years	**₹ 81,60,000**

- **SCALABILITY & MARKET POTENTIAL**
- Noida is currently in the midst of massive commercial and residential development, it is expected to bring in a large number of expatriate families due to the commercial boom. The proximity of the site of the school project to the existing and developing commercial complexes and residential area increases the market value of the project..
  Proximity and accessibility of the site to developing commercial projects:
  Easy access via FNG, Noida Expressway, DND Highway & Pari Chowk.
  Easy access via New Bridge connecting Noida & Greater Noida.
  Proposed Metro Station at Sector 137 within 2 km Radius from the Site
  15 mins drive from City Center Metro Station, Sec 32.
  Samsung India Electronics Private Limited- 10.2km / 19 mins from site

  The project has been designed to satisfy the high IB standards and requirements. Also since there is no other school in the vicinity also ensures a large market demand for the same.

  The construction is set to start as soon as the development of residential projects in the vicinity commence. This is to capture the market at the beginning. So the construction of the school must conclude as soon as new residents begin to settle into the new residential communities.

- **INNOVATION**
  - **GOING BEYOND OUR SCHOOL**

We strive to achieve a business model which extends beyond supporting the institution financially, it attempts in empowering the community to some extent. It presents us an opportunity of giving back to society without having to consider the end users at all in order to prove favourable for all those who are concerned. Our business proposal outlines a plan to sell all the surplus renewable energy generated by our building to power agricultural facilities of those nearby the project site with the aid of a local NGO. An NGO which has already been dealing with agricultural developments shall be preferred. We expect the NGO to reach out to us to let us approach the farmers in the vicinity and help them realize as to how this proposal could be a profitable option for them and make them believe in our scheme which is as follows. The building produces a surplus energy of 25707 kWh annually, which we propose to sell at ₹4/kWh to farms and other agrarian setups. We believe this proposal is feasible for both parties as the farmers pay ₹ 7.3/kWh specifically for farming purposes as per the U. P. Power Corporation Ltd. and if the project were to send the surplus energy back to the grid, the institution would have incurred the rate of ₹ 1/kWh (U. P. Power Corporation Ltd., Net metering). The construction of the electricity line would be taken up by the project partner.

According to this model, the farmers are saving ₹ 84,8331 annually compared to if the facilities took the same amount of electricity from the grid. The project partner also makes a profit of ₹ 77,1818 as opposed to if the electricity was sold back to the grid. The license to sell electricity should be procured by the partner himself. The cost of setting up the business plan is ₹5,299,200 along with ₹8,363,520 for the installations of the solar panels. The building makes ₹2,733,103 in savings from utility bills and ₹102,828 in revenue from the sale of energy. This plan has a payback period of 5 years.

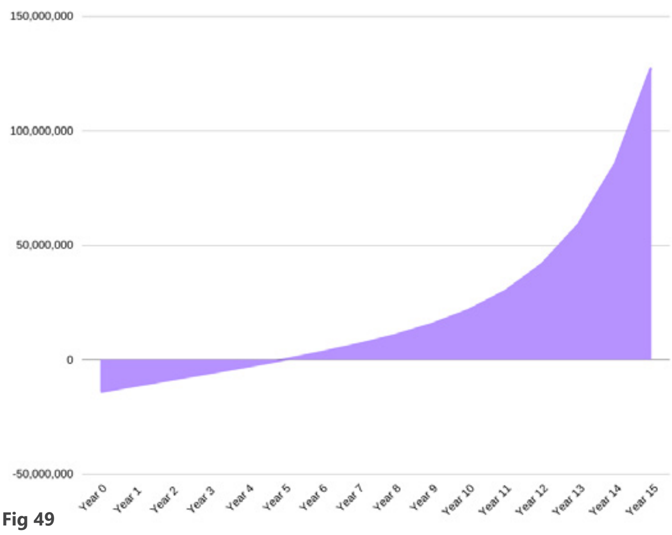


Fig 49

Team Polymorph proposes a Net Zero Energy And Water school building. The project includes solar PV panels on the roof, which produces a surplus energy of 25707.047 KWh. The surplus energy produced will be sold to agricultural facilities for a profit. This revenue can then be used in the operational and maintenance cost of the building, making the net OPEX of the building minimal.
The proposed design is also net zero water, both by reducing the amount of water consumed and re-harvesting storm and wastewater treatment.
For the HVAC system, the proposed design has a much lower cooling load as opposed to the estimated cooling load of base case. The 200 TR difference is accredited to the more efficient building envelope and reduced cooling loads.
The aforementioned strategies reduce the operational cost of the building as the utility cost will be zero.

The team has partnered with several experts and local companies to make the project feasible. All systems used are readily available in India to evade extra charges that would concur during import. The estimated total cost of the proposed building is 2.5% more than the base case cost. This extra cost can be justified with the annual saving in the operational cost of the building, and the revenue brought in by the sale of surplus energy. The chilled water and radiant cooling system comes up to 18% in savings in 20 years when compared to a VRF system. The solar PV panels give us 78.15% in savings in 20 years as opposed to using electricity from the grid. The solar panel has a payback period of 3.17 years when considering the savings from annual electricity bills.

Key Objectives

The team's key objective was to not compromise on the design aspect whilst on the venture to make the project a net zero energy and water building. All guidelines of an IB school have been followed, the classrooms are designed with the unique IB curriculum in mind. The Primary years' classrooms have been designed to be interactive and the older children's classrooms are completely technology enabled, where every workstation has the ability to be connected to the students device.
We have designed spaces such as the Design Tech labs, Language labs and science labs in accordance with the IB curriculum requirement.
The design also pays attention to the circulation of the students and teachers, hence the courtyards and the corridors have been designed accordingly.
Another objective was resilience, an ultraviolet Germicidal Irradiation (UVGI) will be incorporated into the supply air ducts of the Air conditioning system to destroy airborne viruses present in recirculated air. The building is also flood resilient, and ensures energy and water sufficiency during dire situations

The facade of the building consists of terracotta louvers, green walls and heavy duty cement fibre board panels, all designed to clean the air around the envelope. This is both operational and an aesthetic element in the design.

Another one of the team's goals was to go beyond the users of the building, to help promote clean energy not just at the project site. This was the objective of the business plan, where we sell the surplus energy produced by the solar PV panels.

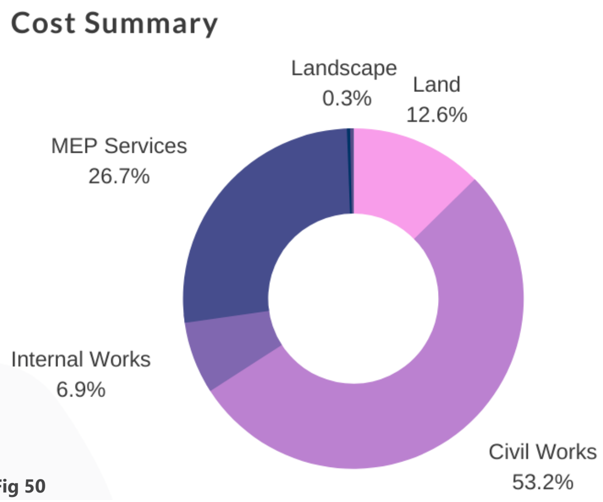


Fig 50