“Final Design Report- April 2021”

February 2021

Educational Building

Team Ferb | Project neev

Ideas Nagpur

IDEAS - Institute of Design Education and Architectural Studies

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A. Executive Summary

Educational Institutes act as a reflection of culture of a particular community group. Built in anticipation of market trends, they represent values that the community intends to inculcate through teaching and learning. Specifically, the design of such institutions must make a student recognize his own design expression and provide spaces for creativity.
Project Neev, i.e., IDEAS, Raipur aims to provide an environment that responds to the needs of the users and is well rooted to its context and culture.
The project not only intends to create a net-zero-energy-water building, but also opens up opportunity for innovation and exploration. Along with sustainability and environment-conscious design, the project also focuses on enhancement of the experience of the users.

Project Neev is an Architecture and Design Institute in Raipur, the capital of Chhattisgarh. Talking about context, one could see various issues in terms of social, environmental,
and economical fronts. The proposal has been thought of as a reflection of solution to those contextual issues. Thus, architecture is seen as a thoughtful response to the Social, Economic and Environmental challenges that the city is facing in the present context.

The design is developed at different hierarchy namely, site level, building level and architectural detailing level. The strategies are well incorporated within these three layers to respond to the contest areas of the competition. It is well-thought on various aspects like Climate, Context, Social Background, function, etc.The form is a resultant of trial-and-error method of different configurations with courtyard spaces, Courtyards being one of the important design strategies adopted for the project. The design configuration generates two major courtyards which is multi-functional in nature and caters to the needs of summers and winters.

The competition gave the team an opportunity to innovate a kinetic façade from scratch. The interactions with professionals, Industry Partners and Academicians pave way for making a designthat is Net-zero-water-energy and also responds to all market trends and standards. The team aims to develop the innovation to its most detailed level which is market ready and contributes towards designing climate responsive and sustainable buildings.

All in all, the project responds to all contest areas and each contest area is related to each another through common strategies. This inter-relationship made sure that a comprehensive design proposal is generated.

B. Team Introduction

Name: Team Ferb

Name of Institutions:

The Institutions participating in the team are:

1. Institute of Design Education and Architectural Studies (IDEAS) Nagpur (Lead)
2. Indian Institute of Technology (IIT) Delhi
3. Yeshwantrao Chavan College of Engineering (YCCE) Nagpur

Division: Educational Building (Typology)

The Team

The 14-member Team consists of undergraduate students with Architectural, Civil and Electrical backgrounds from 3 different institutions. The team is further divided into 3 groups to develop a comprehensive design process which includes a back and forth working pattern.

Sr. No.	Name of Participants	Qualification	Job Roles Legend	
1	Akanksha Bahadure	B.Arch 7th Sem		Comfort and Environmental Quality
2	Amar Shah	B.Arch 7th Sem		Affordability
3	Khushi Daxini	B.Arch 7th Sem		Team Lead
4	Mansi Suchak	B.Arch 7th Sem		Architectural Design
5	Nathulal Suthar	B.Arch 7th Sem		Energy Performance
6	Rigved Nimkhedkar	B.Arch 7th Sem		Architectural Design
7	Shubham Didole	B.Arch 7th Sem		Energy Performance
8	Bhavi Chandrakar	B.Arch 5th Sem		Resilience
9	Kanupriya Chandak	B.Arch 5th Sem		Presentation
10	Sahil Bondade	B.Arch 5th Sem		Innovation
11	Shriya Bagaria	B.Arch 5th Sem		Affordability
12	Tullika Dhandole	B.Arch 5th Sem		Scalability and Market Potential
13	Shubham Kumar	B.Tech Electrical 7th Sem		Engineering Design and Operation
14	Neel Bobade	B.Tech Civil 7th Sem		Water Performance

Table 1: Team members and their job roles

Faculty Profile

Faculty Lead – Dr. Komal Thakur

Dr. Komal Thakur is B,Arch, M. Arch and has done her doctoral degree with her research in "Neighbourhood Microclimate and Building Heat gain" She is an experienced architect in Climate responsive building design and currently working as Associate professor at IDEAS, Nagpur with over 12 years of experience in teaching.

Faculty Advisors:

Prof. Jitendra Farkade

Assistant Professor

B.Arch (VNIT, Nagpur), M.A.A (I.A.A.C Barcelona, Spain) **Experience - 03 years**

Prof. Abhay Purohit

Principal

B.Arch. (V.R.C.E., Nagpur), MCP (IIT, Kharagpur) (Equivalent to Ph.D.) **Experience – 33 years**

Prof. Milind Gujarkar

H.O.D

B.Arch. (Amravati University), M.Arch. (Product Design- SPA, Delhi), Pursuing Ph.D. **Experience – 26 years**

Prof. Ketan Kimmatkar

Associate Professor

B.Arch. (Nagpur University), M. Dip. Landscape Architecture (CEPT, Ahmedabad), Ph.D. **Experience – 20 years**

Figure 1: Faculty Lead and Faculty Advisors

Background of the Lead Institution

IDEAS, Nagpur was started in 2009 with the intention of imparting architectural education in a virtuous manner. It is a pool of architects and designers where all are together to program the education and the faculty is an integral part of the institution. Courses offered – B. Arch and M. Arch.

Figure 2 shows vision mission and goals of the Institute.

Vision	To generate effective synchronization of academicians, professionals, technocrats and students to achieve 'Meaningful Architecture' for the development of the society. To sensitize and train the students to develop a sense of commitment, professionalism and inculcate aspiration for continuous update of knowledge, to serve the local and global community.
Mission	Establishing a centre of excellence in the entire spectrum of Design Education and Application from Product Design to Architecture and from Applied Arts to Fashion Design to serve humanity.
Goals	The school aims at establishing an advance Centre of Learning, turning out creative and technical manpower to play a substantial role in nation-building. IDEAS shall strive to build its image in a way that it acts as a platform for excellent learning at national level having expertise to mould the students to cater to the needs of the society in various areas of human habitat, technology, leadership, culture, administration while maintaining ethical, social and moral values.

Figure 2: Vision, Mission and Goals of the Institute

Industry Partners

Surmount Energy Solutions, Navi Mumbai

Surmount Energy Solutions Pvt Ltd is a pioneer in the Green Building solutions and services. Surmount offers Green Building Facilitation Services, Building Automation Solutions and Building Integrated Photovoltaic for energy generation. It serves some of the largest developers and Government bodies in India and various architects and engineers in the US with its offering. Surmount is a member of USGBC, IGBC, ASHRAE, ISHRAE, BEE, ISLE and core committee of IGBC Green Industrial Buildings.

Figure 3: Logo of Industry Partner

C. Project Background

Project Name - 'Neev'
Project Partner - Institute of Design Education and Architectural Studies (Nagpur)

IDEAS is an architecture Institute (Non-profit Entity) which aims to generate an effective synchronization between professionals, academicians, technocrats and students. To sensitize and train the students, to develop a sense of professionalism and to serve the local and global community, IDEAS wishes to expand its impact further from Maharashtra to now Chhattisgarh by proposing another branch in Raipur.
Key Individual - Prof. Abhay Purohit (Principal, IDEAS - Nagpur)

Brief Description of the Project

Project 'Neev' is an Architecture and Design Institute which aims to provide quality education to the students. It has majorly 2 programs B. Arch and B. Des. The project purpose is defined to be Build-Own-Operate.
i. Location: Raipur, (21.25, 81.62) Chhattisgarh
ii. Climate Zone: Composite Climate
Stage of the Project: Proposed

Figure 4: Location of Raipur

Context and Market Analysis

Raipur being the capital of Chhattisgarh, has evolved as a hub for administration, trade and commerce, education, health and culture. Urbanization has been widely recognized as an indicator of development and has burdened social, economic, technological and environmental fronts of the city. The project tries to focus critically on tapping the existing potential and identifying key development opportunities. The following issues are taken as a challenge to respond to local and regional context. In general, the image of educational institutes is mainly dominated by the infrastructure only and do not contribute to skill enhancement and retaining the indigenous knowledge.

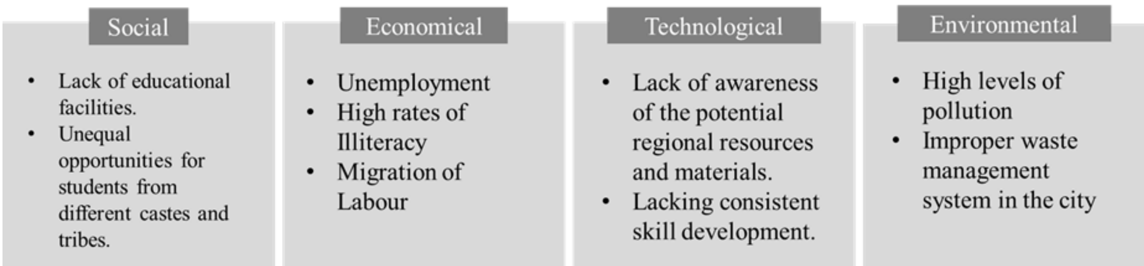


Figure 5: Identifying issues in the local and regional context

What will make a difference?

a. Framework of syllabus that integrates conventional course with indigenous knowledge so that there is an interaction between students and the tribes to come together and contribute for a better future.

b. An institution that provides dedicated workshop areas for interactive teaching and learning between tribal communities and students and the institute itself acting as an example of a building that is modern yet rooted to its genes.

c. Generating employment for people living in outskirts of the city, i.e., for working staff at the institute.

d. An adaptation in built-form is acquired through evolution and conveys advantage that helps to pass its indigenous knowledge to another generation. It typically takes one of three forms: structural, physiological or behavioral. The design should be such that it is well integrated with natural environment.

Site and Building Program

The site (Figure 5) is located in the outskirts of Raipur in Chhattisgarh and has an area of approximately 8000 m^2. It has a linear geometry with the longer axis oriented along the E-W. Major access road is along the east edge of the site connecting it to major locations in the city. The Building program includes two major courses - Bachelor of Architecture (B. Arch) and Bachelor of Design (B. Des) for 3 streams (Graphic Design, Interior Design and Product Design) with an intake of 80 students and 40 students resp. Design institutes have a major portion of the area program dedicated to studios and workshop spaces with other supporting spaces like computer labs, material labs, auditorium, etc.

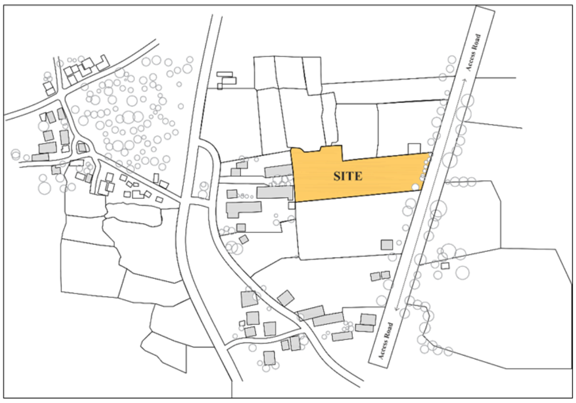


Figure 6: Location of site and nearby context

D. Performance Specification

Climate Zone: Composite Climate

Performance Specification	
Category	**Description**
Envelope	Roof Assembly U Value - 1.104 W/m2.K, Wall U Value - 0.387 W/m2.K, Windows U Value - 1.761 W/m2.K, Window SHGC - 0.568, Windows VLT - 74.5%
HVAC	Radiant ceiling system with 32HPx2 and 20HPx2 Dedicated Outdoor Air Unit For Central fresh air intake and Fan Coil Unit as per room TR having total COP=1.2,ISEER=4.04 And EER=4.2
Lighting (LPD)	Light Power Density - 2.79 W/m2
Electrical (EPD)	Equipment Power Density - 9.66 W/m2
Renewable Energy	Rooftop mounted 250 kwh OnGrid Solar System with Net metring having annual genration 347500 kw
Water System	The freshwater circulation equipment consists of CPVC pipes and two 5-star rated submersible pumps of 1.2HP managed by Variable Frequency Drive (VFD) and 3-Phase control for steady water pressure. The second pump functions at firsts dismissal.
STP	40 KLD - MSEP Fabricated.

Table 2: Performance Specifications

E. Goals of the Project

Contest Area	Goals	Strategies	Achieved Targets
Energy Performance	1. Target Energy Performance Index (EPI) of the building = 78kWh/sq.m/year 2. Target Energy Use Intensity (EUI) of the building = 20 kBTU/sq.ft/year 3. 30% Reduction in energy consumed by HVAC system.	1. Site planning 2. Orientation 3. Open Built Configuration 4. Envelope System 5. Sensor-based Besign and Building Automation 6. Courtyards as microclimate regulator 7. Effecient Appliances and Equipments	1. Achieved EPI = 41 kWh/sq.m/yr 2. Achieved Energy Use Intensity = 12.90 kBTU/sq.ft/year 3. 32.12% reduction in Energy consumed by Radiant cooling as compared to VRF system. Hence reducing total energy consumption by 23%. 4. Achieved Net-Positive energy design
Water Performance	1. Achieving Net-zero water building design 2. Total water consumption for flushing = 2587200 L 3. Reducing flushing water demand by 50% 4. Reducing water consumption demand of irrigation by 40%	1. Low flow plumbing fixtures to reduce water consumed for flushing. 2. Using sensor-based technology to detect moisture and providing optimum amount of water for irrigation. 3. Using Xeriscaping and drip irrigation to reduce water demands for landscaping. 4. Reusing Grey water for Landscaping purpose	1. Achieved Net-Zero Water Design 2. Reduction in water demand of flushing by 50% 3. Total harvested rainwater = 5697342 L 4. Total grey water treated = 3050250 L
Resilience	1. Design of envelope that is resistant to heat waves and provide thermal comfort range of 22°C to 28°C 2. Providing an optimum plinth level to protect the building in case of flood situation 3. Designing a building that is ready in situations of Power outage and Water outage.	1. Designing the building envelope to reduce heat gain and obstruct heat waves. 2. Providing a D.G. set to store power in situations of Power outage. 3. Back-up water reservoir for situation of water outage 4. Providing green roofs and external shading devices	1. Use of Kinetic Façade and shading devices reduce the heat gain and obstruct heat waves. 2. D.G. set capacity = 400KVA; Min Fuel Capacity – 700L - Biodiesel (Batteries power – 30 KAH) 3. Reservoir with capacity of 105000 L
Innovation	1. Cater to the problem of thermal discomfort by designng a building which acts as an element that provides thermal and visual comfort. 2. Promote greenary and ensure enough vegetation for future resilience againts UHI effect to create a healthy micro-climate.	1. Design of Kinetic façade that is optimized for reducing solar heat gain and providing visual comfort. 2. Recycling paper waste into seed paper to maintain vegetation in an around the institute building and ensure comfortable micro-climate.	1. Developed the kinetic façade that has a potential to be a market ready solution. 2. Incorporated waste paper recycling off-site
Affordability	1. To break the investment into phases by proposing a phase-wise construction. 2. Reduce cost of HVAC by using efficient system 3. Reduce energy costs by effective strategies.	1. Phase-wise construction 2. Use of locally available materials to reduce transportation costs and embodied energy. 3. Using efficient electrical appliances to reduce energy costs.	1. Entire construction divided into 3-phase construction 2. Used locally available materials 3. Proposed Radiant Cooling system
Scalability and Market Potential	Develop a product-based element i.e. a kinetic faacde that would generatedemand in the construction industry and become a prototype for future projects. To provide awareness bout use of technology in building design.		Developed a Kinetic Façade that is scalable due to its multi-functionality.
Comfort and Environmental Quality	1. Comfortable hours to be achieved = 7242 hours/year 2. Indoor temperature range = 22-28 °C	1. Heavy roof with over 8hrs time lag 2. Natural ventilation 3. Venturi Effect 4. Use of low VOC bulding finishes	1. Total comfortable hours achieved without HVAC = 5215 Hours 2. Total comfortable hours with HVAC = 8655 Hours
Architectural Design	a. The design will aim to integrate landscape to provide habitable and positive learning environment. b. It would be a blend of architecture, nature and users for cooperative existence. The landscape will be designed using indigenous trees that require minimal maintenance. c. This would envisage an integrated development of indoor and outdoor spaces in total harmony with the surrounding.		
Engineering Design and Operations	1. Use of sensor based design to optimize building systems 2. Use of construction techniques that require less time for construction. 3. Development of the kinetic facade	1. Use of occupancy sensors 2. Incorporating Building automation system 3. Sab design that can be constructed in less time and require less curing. 4. Use of Pile Foundation, AAC block cavity wall, etc.	

Table 3: Goals Targeted, Strategies used and Targets achieved

F. Documentation of Design Process

The team was broadly divided into 3 groups as shown in the figure. An elaborate methodology has been followed that depicts the design process adopted for the project.
The 3 groups worked in 4 stages. The groups were made in such a way that the work each member does in a stage is linked to the work allotted in the next stage. This ensured continuity and clarity in terms of understanding the concepts and taking them to the level of final detailing. The team divided the entire design process into 4 parts.

1. Decode
2. Define
3. Develop
4. Detail

DECODE
The first stage of the process mainly focused on decoding the requirements of the project partner, studying the site and the resources available. Understanding the 10 contest areas of the competition was important to link requirements of site and project partner with the competition goals. These requirements helped to assign roles of the team members and to make primary decisions before starting with the design of the educational institute.

This stage required discussions with the project partner, faculty lead and a site visit to Raipur. The team visited Raipur to understand the context and the available market. The following figure 6 shows work done in the first stage.

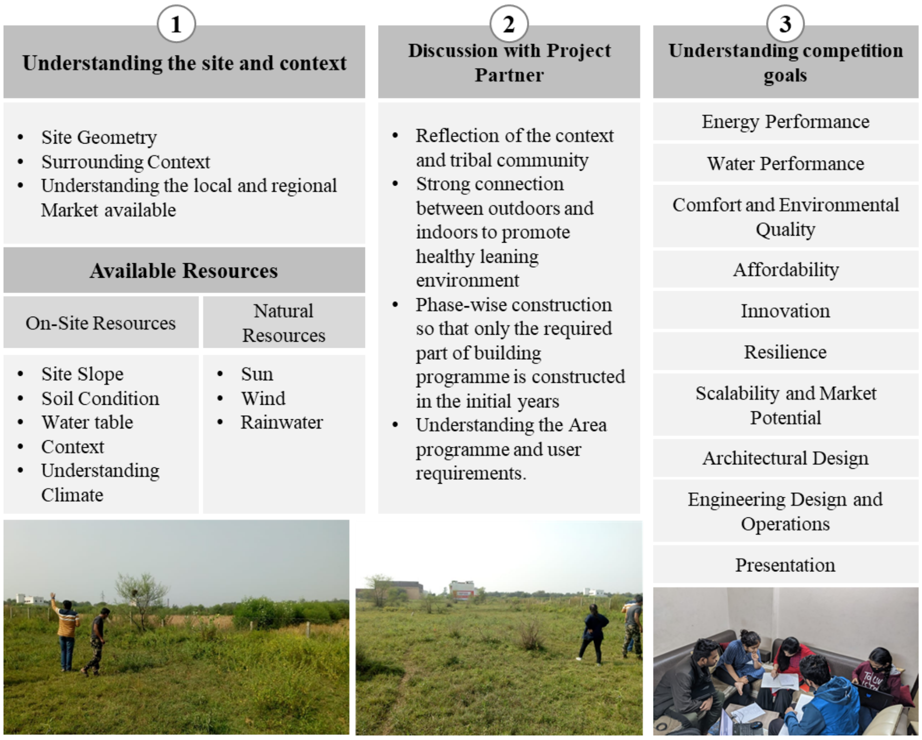


Figure 7: Understanding DECODE (Site visit photographs and discussions with the Faculty Lead)

DEFINE

At this stage, the team members started defining goals for the project. Targets and goals for each contest area were set taking into consideration the requirements of the project partner. Thus, detailed discussions for formulating strategies to achieve those targets were required.

As a part of a basic concept the team followed, Architecture is one such contest area that has potential to improve the performance of the rest of the contest areas in some or the other ways. Hence, major decisions were taken on the architectural design part first to maximize the performance of other contest areas.

Discussions on building program, users and their requirements were held to come up with conceptual zoning and massing. As a result of climatic analysis, the orientation of the building was decided. The sun path was considered to develop the massing of the building to ensure mutual shading. According to the directions of the wind, open pockets were created that allow cross ventilation. Through this process, the built-form started taking shape and the team started defining an architectural vocabulary to be adopted. At this stage, the team had their first online meeting with the Industry Partner. Competition requirements, goals, schedule and basic concept was discussed as shown in figure 7, figure 8 and figure 9.

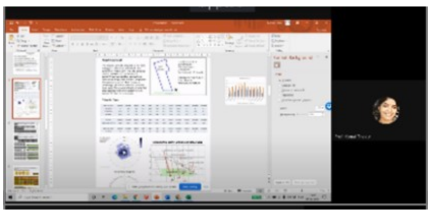


Figure 9: Discussion with Faculty Lead

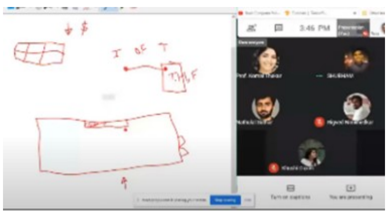


Figure 8: Discussion with Industry Partner

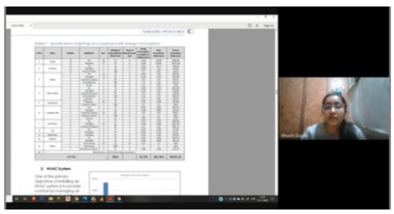


Figure 10: Discussion with the Team

DEVELOP

After defining basic zoning and circulation, form of the building was developed as a response to sun, wind and daylight. The following (figure 10) shows development of form and the process of massing and modulation that was adopted.

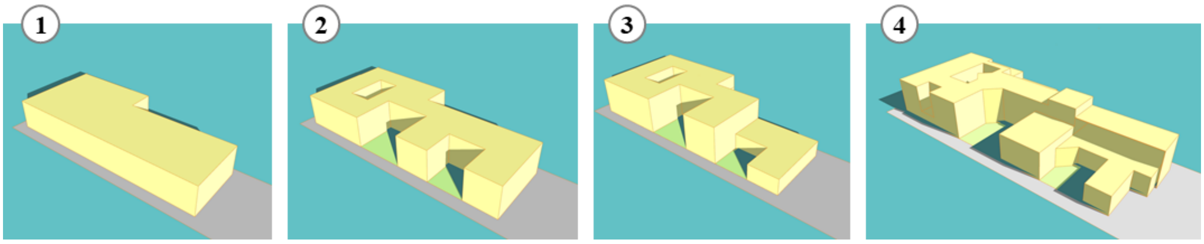


Figure 11: Development of Form

At this stage, the development of design was done simultaneously with the development of the building systems. The Table shows how a particular design development stage is linked to the development of building systems and services. This ensured effective link between the design and the detailing.

This was the time when the industry partner team had a significant role in guiding us. Thus, members from the team visit the Industry Partners office for one-to-one discussion. The team presented the work till date to the Industry Partner and asked for doubts and other reviews.

Design Development	Development of Building systems
Form Development	Integrating site development details, offsets, F.S.I Norms, etc. with developing forms.
Circulation and movement pattern	Circulation that responds to services systems, locations of water storage tanks, parking, site circulation, etc.
Zoning Massing	Mass modulation such that it generates terraces for solar installations, terrace landscaping and shading.
Material Analysis	Materials that reduce heat gain, thus reducing cooling loads on HVAC system.
Development of Façade	Appropriate design of shading devices and optimizing for efficient daylighting.
Open-Built configuration for micro-climate analysis	Providing courtyards for water management, rainwater harvesting, thermal comfort strategy for optimizing microclimate and providing venturi effect for ventilation evaporative cooling.
Developing Passive techniques	Developing strategies for venturi effect, stack effect, shading devices, cross ventilation, evaporative cooling etc.
Pre-Design Simulations	Experimenting with pre-design simulations for daylight, heat gain, wind movement, etc.

Table 4: Relation between design development and development of building systems

The team discussed various aspects of the competition goal like energy performace, water performance, etc. The development and detailing of the kinetic façade was first discussd with them.

Also, the Industry Partner team organized a live case study visit to EIL Building in Mumbai. It is a net-zero office building. The aim was to understand how services are integrated in the design of a green building. This case study was helpful because field experts were present to there to explain the entire working of the net zero building.

The figure 12 shows pictures of the team with EIL team and services that were observed and understood with respect to net-zero building.

Figure 12: Meeting with Industry Partner and Live Case Study of EIL

DETAIL

Final detailing of the Design and systems was a part of this Last stage. Detailing in terms of costing, material requirements, simulation results, construction detailing, etc. was required to reach to the final level of the proposal.

The project partner was involved to validate the design decisions and costing parameters. Discussions with the faculty lead and faculty advisors were held and Industry Partner was also approached to have a doubt clearing session for simulations, HVAC system, Lifecycle cost analysis, etc.

G. Design Documentation

This section explains all the ten contest areas in detail and how the team has tried to design the educational building keeping in mind the competition goals.

The process of design started with understanding the 9 contest areas and how they are inter-related with one another. This process helped the team to strengthen the proposal in totality.

The first step was to list down how each contest area performs at different levels, i.e., at site level and building level. The following table 5 depicts the strategies used at site and building level for all the contest areas.

Sr. No.	Contest Area	Site Level	Building Level	Other Strategies
1	Energy Performance	Orientation	Material Specification	Efficient electrical appliances
		Zoning	Daylight Shelves	Use of occupancy sensors
		Massing	Kinetic Façade	
		Solar Generation	Radiant cooling system	
		Landscaping	Green roof	
			Courtyards as micro-climate regulator	
			Downdraft system	
			cross ventilation	
			Fins	
			Cavity Wall	
			One-room deep concept	
2	Water Performance	Rainwater Harvesting		Use of Low flow fixtures
			Courtyards	
		Xeriscaping -Landscape Design	Provision of STP	Porous concrete Tiles
3	Resilience	Early warning system	Emergency reservoir and pump stations	Cool roof tiles
			Provision of DG set	
			Fins	
			Kinetic Façade	
			Green roof	
			Courtyards	
			Xeriscaping -Landscape Design	
			Material Specification	
4	Affordability		Materials Used and structural system	Phase-wise construction
			Xeriscaping -Landscape Design	
			Radiant Cooling	
5	Innovation	Tackle UHI by integrating use of seed paper	Kinetic Façade	AI and IOT for future
6	Scalability and Market Potential		Kinetic Façade	
			Radiant Cooling	
7	Comfort and Environmental Quality	Open and built configuration	Courtyards	Downdraft system
		Landscape Design	Fins	
			Kinetc Façade	
			Shading Mask (OAT)	
			Materials used	
			Cavity Wall	
			Green Roof	
			Envelope system	
			Cross ventilation	
			Daylight Shelves	
			One room deep concept	
			Radiant Cooling	
8	Architecture	Zoning	Materials used	Architectural Character
		Massing	Daylight Shelves	
		Circulation	Fins	
			Envelope system	
		Site Development	Kinetic Façade	
		Landscape Design	Courtyards	
			One room deep concept	
			Terraces	
9	Engineering Design and Technology	Rainwater Harvesting	Occupancy sensor based operation	Kinetic Façade
			Structural System	
			Electrical System	
			Plumbing system	
			Radiant cooling	
			Sewage Treatment	
			Solar Generation	

Table 5: Strategies used at different levels for each contest area

Contest Areas	Energy Performance	Water Performance	Resilience	Affordability	Innovation	Scalability and Market Potential	Comfort and Environmental Quality	Architecture	Engineering Design and Technology
Energy Performance		5, 11,	6, 8, 10, 11, 20	6, 9,	8,	8, 9,	5, 7, 8, 9, 10, 11, 13, 19, 20	2, 3, 5, 6, 7, 8, 11, 13, 20	4, 8, 9, 14, 15,
Water Performance	5, 11,		11, 17, 18,	17,			5, 11, 12,	5, 11,	16,
Resilience	6, 8, 10, 11, 20,	11, 17, 18,		6, 17,	8,	8,	6, 8, 10, 11, 20	6, 8, 11, 20	8,
Affordability	6, 9,	17,	6, 17,			9,	6, 9,	6,	9,
Innovation	8,		8,			8,	8,	8,	8,
Scalability and Market Potential	8, 9,		8,	9,	8,		8, 9,	8,	8, 9,
Comfort and Environmental Quality	5, 6, 7, 8, 9, 10, 11, 12, 13, 19, 20,	5, 11,	6, 8, 10, 11, 20,	6, 9,	8,	8, 9,		5, 6, 7, 8, 11, 13, 20	8, 9,
Architecture	2, 3, 5, 6, 7, 8, 11, 13, 20,	5, 11,	6, 8, 11, 20,	6,	8,	8,	5, 6, 7, 8, 11, 13, 20,		8,
Engineering Design and Technology	4, 8, 9, 14, 15,		8,	9,	8,	8, 9,	8, 9,	8,	

Table 6: Inter-relationship between contest areas through common strategies

The next step was to identify the common strategies in all contest areas. That gave the team an understanding of the strategies that affect the contest areas. The more a strategy is repeated, it is inferred that the strategy is effective and has the potential to improve the performance of those particular contest areas. Below is a list of all major strategies Figure 12 that have contributed towards performance of the contest areas. Table 6 shows a detailed analysis of the strategies according to the 9 contest areas.

1. Orientation
2. Zoning
3. Massing
4. Solar Generation
5. Landscaping
6. Material Specification
7. Daylight shelves
8. Kinetic Façade
9. Radiant cooling system
10. Green roof
11. Courtyards as micro-climate regulator
12. Venturi effect and cross ventilation
13. One-room deep concept
14. Efficient electrical appliances
15. Use of occupancy sensors
16. Rainwater Harvesting
17. Xeriscaping
18. Porous concrete Tiles
19. Cavity Wall
20. Fins

Figure 13: Legend (List of Strategies)

From the above table 6 we infer that the entire proposal is designed to enhance performance of contest areas not individually but in coordination to other contest areas too. Below is an illustration (Figure 14) that comprehensively depicts the intensity of relationship of one contest area to the other.

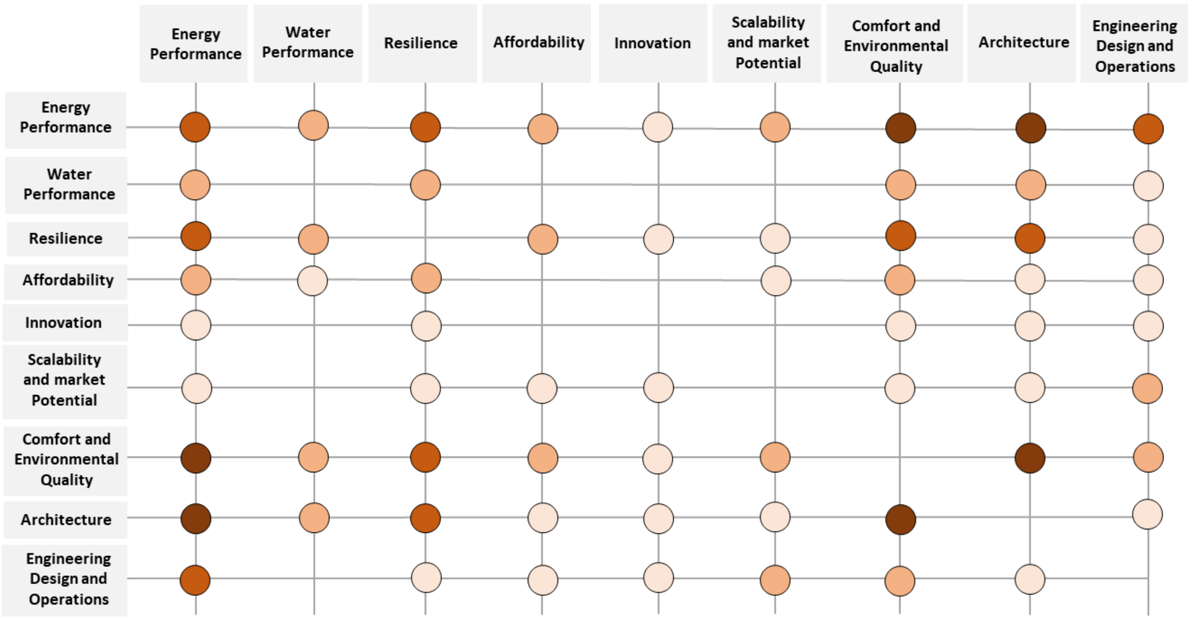


Figure 14: Intensity of Relationship between contest areas

a. Energy Performance

Energy Consumption Calculation

The total energy consumption of the building is optimized for calculated number of days eliminating Sundays, non-working Saturdays and National holidays. The following table 7 shows total number of working days after considering holidays. The total number of holidays considered are 230 days.

Table 7: Number of Holidays considered

Holidays	No. of Days
Govt. Holidays	20
Summer Vacations	52
Saturday & Sunday	72
Miscellaneous Add on	20
Total Holidays	230

Months	Tubelights	Fans	Radiant Cooling + DOAS	Equipments	Lift	S.T.P	Pumps	Kinetic Facde	Total By Months
January	2417.04	1398.96	21268.8	8355.6	288	64.512	468.48	518.4	**34779.792**
February	2215.62	1282.38	19496.4	7659.3	264	59.136	429.44	475.2	**31881.476**
March	2215.62	1282.38	19496.4	7659.3	264	59.136	429.44	475.2	**31881.476**
April	302.13	174.87	2658.6	1044.45	36	8.064	58.56	64.8	**4347.474**
May	201.42	116.58	1772.4	696.3	24	5.376	39.04	43.2	**2898.316**
June	2215.62	1282.38	19496.4	7659.3	264	59.136	429.44	475.2	**31881.476**
July	2417.04	1398.96	21268.8	8355.6	288	64.512	468.48	518.4	**34779.792**
August	2517.75	1457.25	11077.5	8703.75	300	67.2	388	540	**25051.45**
September	2316.33	1340.67	20382.6	8007.45	276	61.824	448.96	496.8	**33330.634**
October	2114.91	1224.09	18610.2	7311.15	252	56.448	409.92	453.6	**30432.318**
November	1611.36	932.64	14179.2	5570.4	192	43.008	312.32	345.6	**23186.528**
December	2316.33	1340.67	4076.52	8007.45	276	61.824	301.76	496.8	**16877.354**
Total	22861.17	13231.83	173783.82	79030.05	2724	610.176	4183.84	4903.2	

Table 8:Monthly Calculation of energy consumption

A detailed calculation of energy consumption by different components per month has been shown in the table 8. The total energy consumption is mainly due to Electrical appliances, Radiant Cooling, Services and Kinetic Façade. Figure 16 shows a detailed break-up of energy consumption and it can be inferred that a major part i.e., 57% of the electrical energy is consumed by Radiant Cooling system.

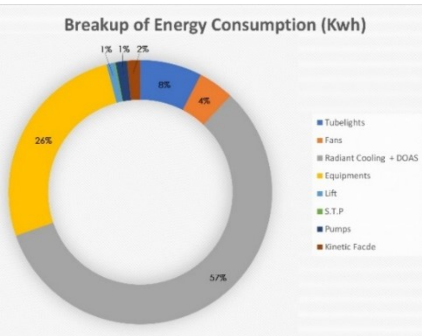


Figure 16: Break-up of Energy Consumption

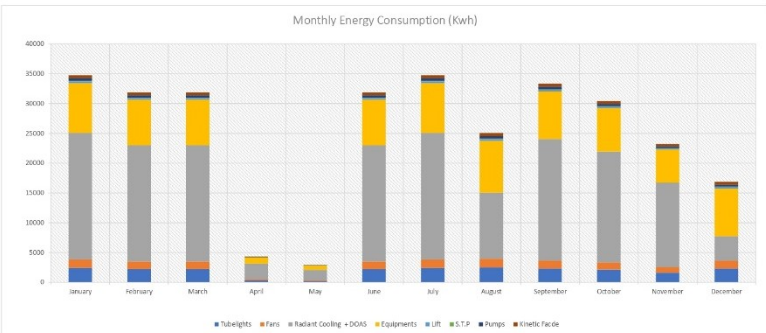


Figure 15: Monthly Energy Consumption

Radiant Cooling as an efficient strategy for energy performance

The figure 17 shows a graph comparing energy consumed by conventional VRF system and Energy consumed by proposed Radiant cooling system. Hence, it can be concluded that Radiant cooling system is comparatively more energy efficient than VRF system. The radiant cooling system consists of different components as listed in the table 9. Energy consumed by each component per year has been detailed out.

Annual Consumption		
Appliances	Radiant (Kwh)	Conventional (Kwh)
Chillers/cooling towers	74584.4	121430.8
DOAS	119600	165600
Chilled water pump (gpm)	1840	4416
Fan coil units	9641.6	11555.2
Total	205666	303002

Table 9: Annual energy composition by components of HVAC

Use of efficient Electrical Appliances

The total energy consumption of a building is also a function of the electrical appliances that are installed. Therefore, efficient appliances are proposed in order to minimize the total electrical energy demands. The figure shows list of electrical appliances used for the project with due consideration to the cost of each appliance. The proposed electrical appliances reduce electrical demands by _% as shown in the graph in the figure. It shows a comparison between conventional and proposed electrical appliances.

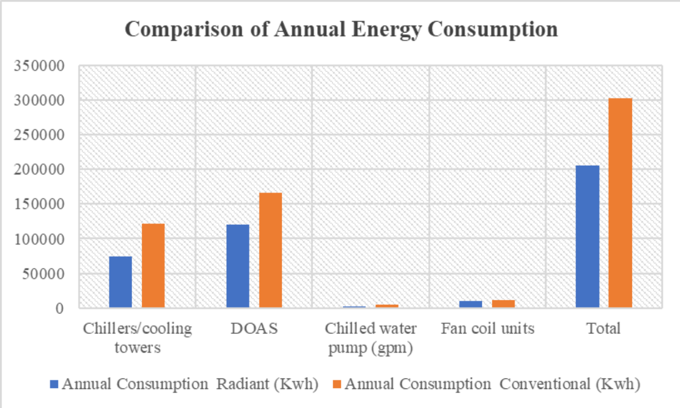


Figure 17: Comparison of Energy Performance of VRF and Radiant Cooling

SR.NO	ASSETS	Brand	SPECIFICATION	CONSMP / W	UNITS	Cost /PER	Total Cost
	ELECTRICAL INSTALLATION & EQUIPMENTS						
1	Fan	ORIENT ELECTRIC	Sweep-1200 mm, BLDC Motors and 65% Electricity saving	25.00	621.00	₹ 3,900.00	₹ 24,21,900.00
2	Exhaust Fans	ATOMBERG-RENESA	Sweep-150 mm, 20W Energy-Efficient BLDC Motors	12.00	24.00	₹ 1,990.00	₹ 47,760.00
3	Internet Modem	TP-Link WiFi 6 AX3000	…	18.00	25.00	₹ 7,000.00	₹ 1,75,000.00
4	Lawn Movers	BLACK+DECKER BEMW451BH-GB	4 Inch Winged Blade	1200.00	1.00	₹ 9,000.00	₹ 9,000.00
5	Microwaves	IFD Microwaves oven	…	1200.00	1.00	₹ 5,000.00	₹ 5,000.00
6	Refrigerators	LG direct cool 90L	…	29.00	1.00	₹ 16,000.00	₹ 16,000.00
7	Deep freezers	Epson	….	500.00	2.00	₹ 30,000.00	₹ 60,000.00
8	Tubelights	PHILIPS- LED TUBE LIGHTS	Made from Plastic, aluminium and electronics and components can be e-cycled.	25.00	922.00	₹ 600.00	₹ 5,53,200.00
9	Ceiling Lights	ERD-DOWNLIGHT ROUND	Up to 90% energy saving long lasting and eco friendly	20.00	200.00	₹ 975.00	₹ 1,95,000.00
10	Xerox Machine	CANON IR 2318L	….	300.00	1.00	₹ 50,000.00	₹ 50,000.00
11	Attendance machine	REALTIME Power of Biometrics T5	….	3.00	4.00	₹ 5,000.00	₹ 20,000.00
12	Sound system	Bosch LBD0606 Ceiling Speakers	….	15.00	24.00	₹ 725.00	₹ 17,400.00
13	Vending machine (Tea/ Coffee)	Cafe DESIRE	….	220.00	1.00	₹ 16,000.00	₹ 16,000.00
	TOTAL			3567.00		₹ 1,46,190.00	₹ 35,86,260.00
	WATER SUPPLY						
14	Water Pumpus	LUBI" 0.5 HP Pressure pump - Mega Booster - II	….	360.00	4.00	₹ 7,839.00	₹ 31,356.00
	TOTAL			360.00		₹ 7,839.00	₹ 31,356.00
	AUDIO VISUAL EQUIPMENT						
15	Telivision	LG 19 inch HD Ready Monitor	…	5.00	1.00	₹ 6,000.00	₹ 6,000.00
16	Projectors	BenQ MS527P DLP Projector	…	270.00	11.00	₹ 26,500.00	₹ 2,91,500.00
17	Close Circuit Camera Security System	Panasonic WV-S3532LM	….	15.00	15.00	₹ 2,000.00	₹ 30,000.00
18	Music Systems	JBL Bar 5.1 Channel Sound Bar	….	550.00	1.00	₹ 50,000.00	₹ 50,000.00
	Total			840.00		₹ 84,500.00	₹ 3,77,500.00
	COMPUTERS & ACCESSORIES						
19	Computers	Asus.tk	….	200.00	120.00	₹ 80,000.00	₹ 96,00,000.00
20	Scanners	Epson Perfection V39 Color Photo and Document Scanner	….	150.00	4.00	₹ 5,000.00	₹ 20,000.00
21	Printers	HP Laserjet Pro M17a Single Function USB	….	250.00	8.00	₹ 9,000.00	₹ 72,000.00
	TOTAL			600.00		₹ 94,000.00	₹ 96,92,000.00
			GRAND TOTAL				₹ 1,36,87,116.00

Table 10: Details of Efficient Electrical Appliances used

EPI Calculation

Thus, considering effective energy consumption optimization strategies the final energy consumption per annum is 332814 kWh and the Total Built-up area is 8177 m^2. Therefore, Energy Performance Index (EPI) = 41 kWh/sq.m/year Energy Use Intensity = 12.90 kBTU/sq.ft/year

Total Consumption	332814.6
Total Built up Area	8177.03
EPI	**41**

Table 11: EPI Calculation

Solar Generation

The site receives direct solar radiation giving an opportunity to use it as a potential source of renewable energy generation. The solar panels are installed at the terraces at an appropriate location to protect from any kind of surrounding shading. The technical details of the PV system have been shown in the figure. The generated renewable energy is mostly consumed by the building and the additional generation is supplied to grid.

50KW On Grid Solar Plant			**200KW On Grid Solar Plant**		
Sr.No	Particular	Description	Sr.No	Particular	Description
1	Solar System	50Kw	1	Solar System	200kW
2	Mono crystalline Panels Capacity	320 watt	2	Mono crystalline Panels Capacity	320 watt
3	Solar Panel Qty	150 Nos.	3	Solar Panel Qty	600 Nos.
4	On Grid Solar Inverter	50 kW	4	On Grid Solar Inverter	200 kW
5	Tin Shed Mounting Solar Structure	50KW	5	Rooftop Mounting Solar Structure	200KW
6	ACDB/DCDB Box	2Nos.	6	ACDB/DCDB Box	8 Nos.
7	Wires AC/DC	700 Meters	7	Wires AC/DC	2800 Meters
8	Earthing	1 Sets	8	Earthing	2 Sets
9	Lighting Arrestor	1 Sets	9	Lighting Arrestor	2 Sets
10	MC4 Connector	12 pairs	10	MC4 Connector	4 pairs
11	Other Fitting	1 Sets	11	Other Fitting	4 Sets
12	Space required	400 Sqm	12	Space required	1600 Sqm
13	System Generation/1kwh=5kwh/day	73000 KWH / Year	13	System Generation/1kwh=5kwh/day	292000 KWH / Year
14	System Warranty	5 Years	14	System Warranty	5 Years
15	Solar Panel Warranty	25 Years	15	Solar Panel Warranty	25 Years
16	Price Range	Rs. 21,00,000 (Latest price including installation)	16	Price Range	70,00,000 (including installation latest price

Table 12: Details of Solar Generation System

Calculations showing net-zero energy design

The above figure depicts a monthly comparison of energy generation to energy consumption. It can be deduced that the proposal is a net-positive design with total generation greater than the total annual consumption as can be seen in the graph. Net-positive energy system allows interaction with the grid and surplus energy can be sent the grid.

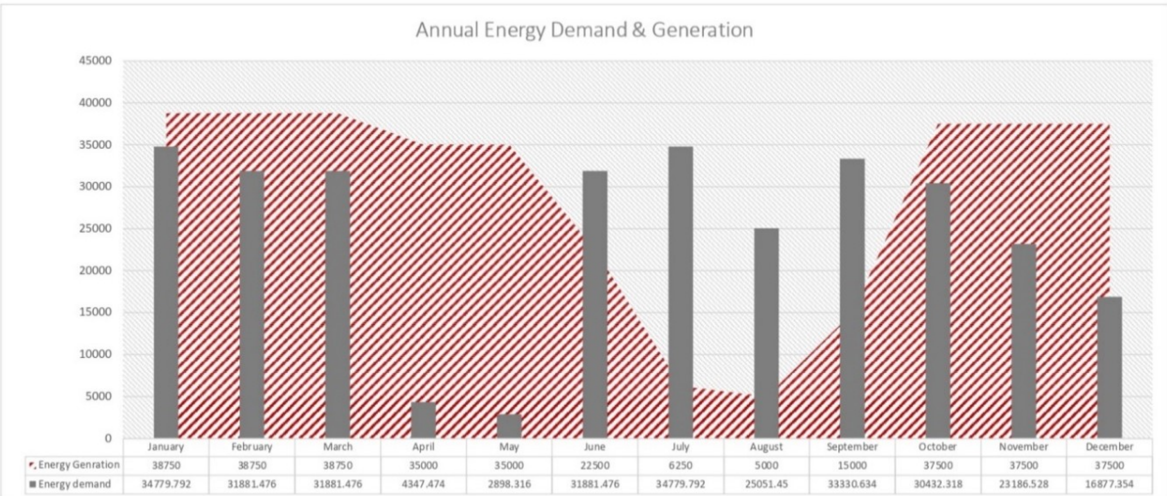


Figure 18: Comparison of Energy consumption to Solar Generation

Building Envelope Design and Energy Performance

Pre-Design Simulation

The predesign simulations for daylighting and solar heat gain gave the team a basic configuration of the building. The concept of one room deep planning by providing courtyards ensures enough daylighting in the spaces and hence reduces the demand for artificial lighting. Hence, a basic planform was designed. The figure shows simulation for daylighting that is achieved by using one-room deep planning.

A major part of the building program is dedicated to studio spaces. Thus, simulations for optimizing daylighting and solar heat gain were run taking into consideration the WWR and the SV ratio. The required illumination on the working desk is 300 to 700 lux as mentioned in the National Building Code (NBC). The 9-cube method was used. These 9 cubes in which the central block defines the courtyard space is simulated to get the suitable location of studio space according to the daylight and solar heat gain. A combination of 6 models were simulated as shown in the figure.

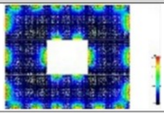
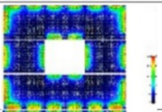
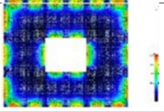
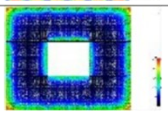
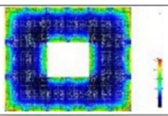
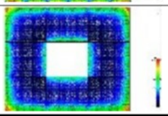
Sr. no.	Parameters	Daylight (Gradient, Avg. Illuminance)		Solar Gain kW
1	Studio size - 12m x 10m Courtyard Planning Height - 3.5m WWR - 30%		523.89	8.13
2	Studio size - 12m x 10m Courtyard Planning Height - 5m WWR - 30%		495.19	21.03
3	Studio size - 12m x 10m Courtyard Planning Height - 3.5m WWR - 40%		689.62	11.05
4	Studio size - 12m x 10m Courtyard Planning Height - 5m WWR - 40%		644.55	31.86
5	Studio size - 12m x 10m Courtyard Planning Height - 3.5m WWR - 50%		846.02	15.33
6	Studio size - 12m x 10m Courtyard Planning Height - 5m WWR - 50%		780.32	39.79

Figure 19: Pre-Design Simulation for Heat gain and Daylighting

Observations: Model 5 with WWR 50% and Building height 3.5m provides the best conditions for working in studio with average illuminance 846.02 lux and solar gains 15.33 After selecting the best configuration of WWR and height of building the team proceed with demarcating spaces according to the solar heat gain of a single unit and ventilation requirements of the space.

For example, units with maximum heat gain will be used for tertiary activities and units with minimum heat gain will be used for primary activities i.e., for studio spaces. Next step was to design an envelope system that minimizes the heat transfer from the exterior to the interior. The envelope includes walls, roof and window. Detailed research on the material specification of the envelope system was done to shortlist a few configurations of wall, roof and window type. The material sets were simulated to find the cooling loads and were optimized for U-Value, availability and cost. A detailed comparison of the material sets has been shown in the figure

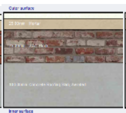
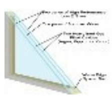
SETS	Wall			Roof			Glazing		
	SET A	SET B	SET C	SET A	SET B	SET C	SET A	SET B	SET C
Layer 1	Brick - 115mm	AAC Block - 115mm	Brick - 115mm	Concrete Slab - 100mm	Concrete Slab - 100mm	Concrete Slab - 100mm	Generic Clear - 3mm	Generic Clear - 6mm	Generic LoE Clear - 6mm
Layer 2	Air Cavity - 50mm	Air Cavity - 50mm	Air Cavity - 50mm	Brick - 75mm	AAC Block - 75mm	Hard Rubber - 75mm	Air - 6mm	Air - 13mm	Air - 13mm
Layer 3	AAC Block - 115mm	AAC Block - 115mm	Brick - 115mm	Mortar - 25mm	Mortar - 25mm	Mortar - 25mm	Generic Clear - 3mm	Generic Clear - 6mm	Generic Clear - 6mm
Layer 4	Plaster - 13mm	Plaster 13mm	Plaster 13mm	Tiles - 12mm	Tiles - 12mm	Tiles - 12mm			
Section									
U-VALUE	0.598 W/m2K	0.387 W/m2K	1.234 W/m2K	1.104 W/m2K	0.674 W/m2K	0.768 W/m2K	2.551 W/m2k	2.665 W/m2k	1.761 W/m2k
MATERIAL COSTING	RS. 6420/cubic meter	Rs. 6300/cubic meter	Rs. 6570/cubic meter	Rs.3200/cubic meter	Rs.3350/cubic meter	Rs.3100/cubic meter	Rs. 12542/sq.m	Rs. 12542/sq.m	Rs. 13379/sq.m
AVAILABILITY	25Km - 30Km radius			30Km radius			Within 15 Km radius		
COOLING LOAD	451.5	448.5	452.67	434.27	437.48	435.44	460.39	458.61	451.42

Table 13: Comparison of Material Sets for Envelope Design

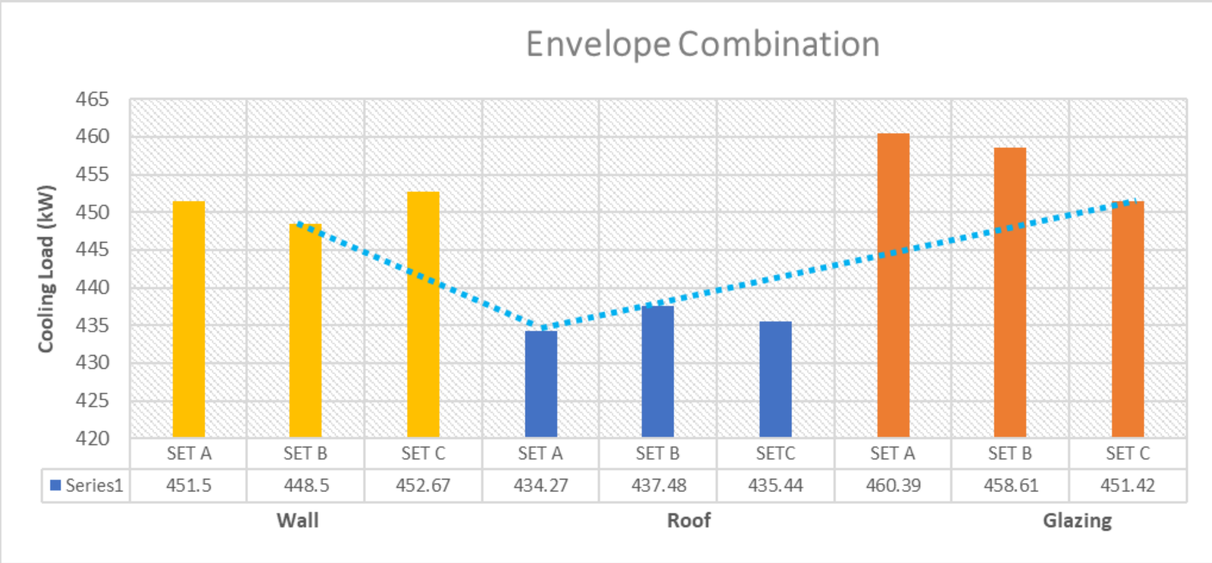


Figure 20: Comparison of Envelope Combinations

Design of Fins as shading Device

The façade was designed to minimize the solar heat gain with the use of fins that are inclined at an angle of 70°. The angle was derived for the specific location from the book Sun, Wind and Light. The inclined fins avoid direct solar radiation on the windows, thus reducing the solar heat gain in the interior spaces. Minimizing the solar heat gain in turn reduces the cooling load as shown in the comparison graph in the figure.

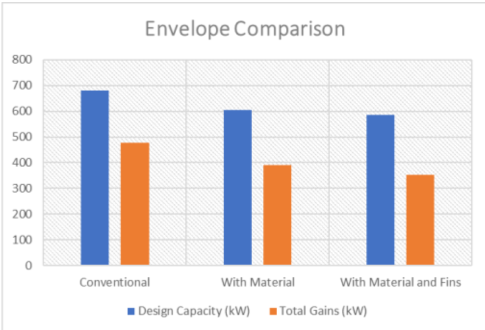


Figure 21: Comparison of Cooling Load and heat gain with and without Fins

b. Water Performance

This contest area focuses on incorporating water management systems and strategies that contribute towards creating a Built-form that is Net-Zero-Water. The water cycle diagram shows source, treatment and circulation of water with specified volumes. The freshwater circulation equipment as shown in Figure consists of CPVC pipes and two 5-star rated submersible pumps of 1.2HP managed by Variable Frequency Drive (VFD) and 3-Phase control for steady water pressure. The pump fills the overhead tank of 30KL. The second pump functions at firsts dismissal. The pump functions once a day to fill up OHT. The overall water requirement is reduced by 55% by using low flow fixtures and an efficient water supply system.

The water required for flushing and landscaping purpose is fulfilled by collecting and treating the generated grey water from canteen kitchen and toilet areas. The Sewage treatment plant treats the grey water, caters to flushing and irrigation purpose and the sludge is supplied to the municipal sewage line.

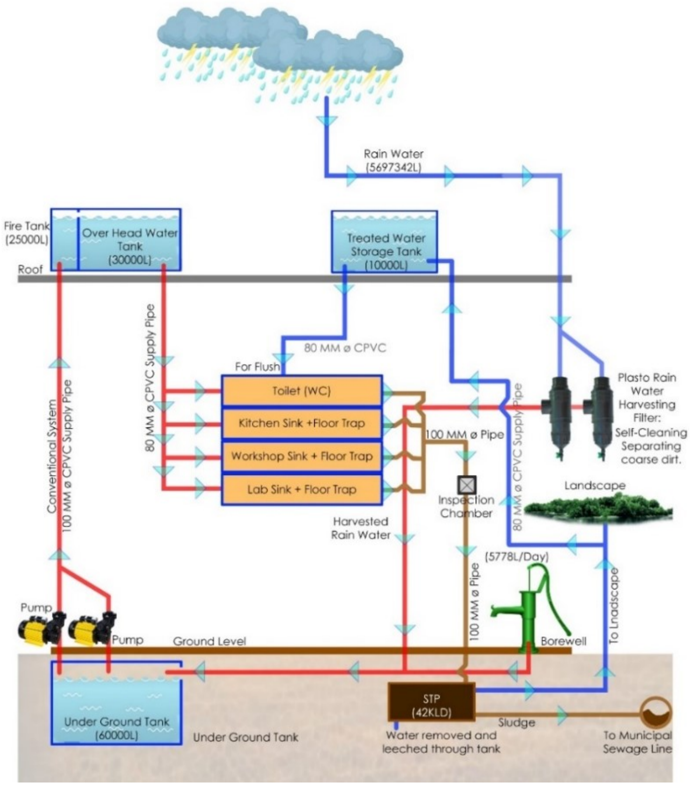


Figure 22: Water-Cycle Diagram

The following tables show annual water demand and annual water harvested respectively. Considering 700 users on an average on campus every day, the demand has been calculated. Number of days per month have been optimized by considering holidays like Sundays, Saturdays and National Holidays.

CONSUMPTION							
Month	Days in month	Domestic Use (L)	Cooling Use %	Cooling Use (L)	Irrigation Use %	Irrigation Use (L)	Total Consumption (L)
July	25	6,12,500	90%	14,974	5%	832	6,28,306
August	25	6,12,500	80%	13,310	5%	832	6,26,642
September	24	5,88,000	50%	7,986	50%	7,986	6,03,972
October	25	6,12,500	75%	12,478	30%	4,991	6,29,969
November	24	5,88,000	20%	3,194	90%	14,375	6,05,569
December	25	6,12,500	0%	-	90%	14,974	6,27,474
January	25	6,12,500	0%	-	90%	14,974	6,27,474
February	22	5,39,000	20%	2,928	90%	13,177	5,55,105
March	25	6,12,500	50%	8,319	90%	14,974	6,35,793
April	3	61,250	90%	1,497	90%	1,497	64,245
May	3	61,250	100%	1,664	90%	1,497	64,411
June	24	5,88,000	90%	14,375	90%	14,375	6,16,750
Total		**61,00,500**		**80,725**		**1,04,484**	**62,85,709**

Table 15: Annual Water Consumption

Month	Days in month	Rainfall (mm)	Effective rain (mm)	Effective Area (m2)	Harvested water (l)	Grey water generated (l)
July	25	328	323	5147	1662368	306250
August	25	333	328	5147	1688101	306250
September	24	188	183	5147	941837	294000
October	25	45	40	5147	205866	306250
November	24	6	1	5147	5147	294000
December	25	6	1	5147	5147	306250
January	25	10	5	5147	25733	306250
February	22	13	8	5147	41173	269500
March	25	18	13	5147	66906	306250
April	3	12	7	5147	36027	30625
May	3	22	17	5147	87493	30625
June	24	186	181	5147	931544	294000
Total Harvested water					**5697342**	**3050250**

Table 14: Annual Water Harvested and Reused

Figure 23 shows water balance bar graph that compares monthly water consumption to the amount of water harvested and grey water reused.
An ideal net zero water building uses on-site alternative water sources to supply all of the building's water needs. All wastewater discharged from the building is treated on-site and returned to the original water source. Thus, the proposal uses harvested rainwater and reuses generated greywater to meet water demands.

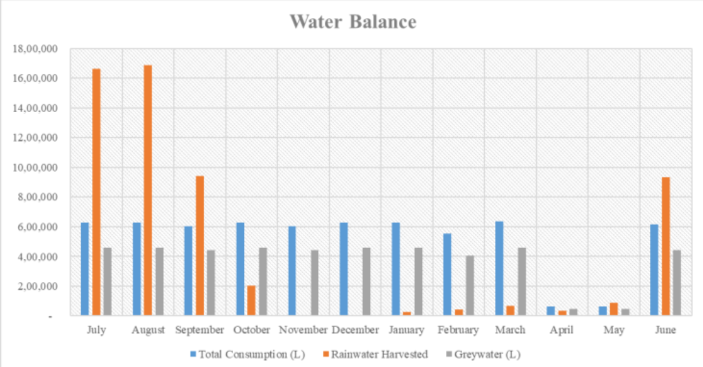


Figure 23: Water Balance Chart

Strategies adopted to make the building net-zero-water:

1. Efficient on-site water management system
2. Landscape design that is water efficient
3. Use of low flow plumbing fixtures
4. Providing Sewage Treatment and waste water management system

The entire plumbing system has been provided with low flow fixtures that reduce the water demands by 55%. List of all plumbing fixtures used, its efficiency and costing has been provided in Table 16.

Product	Company name	Specification	Water saving %	Size	Price	Model
Water Closers	CERA	COMPACT - Wall hung EWCs	IAPMO certified. Water saving up to 30%.	490 x 350 x 330 mm	Snow-White: Rs. 4,850/-	
Urinals	CERA	CICILY - Urinals with integrated EFS	IAPMO certified. Water saving up to 25%.	320 X 300 X 525 mm	Snow-White: Rs. 13,610/-	
Water Taps	CERA	CRAYON - Pillar cock with aerator.	IAPMO certified. Water saving 41%		Rs. 1,190/-	
Sink Cock	CERA	DRIVE - Sink cock (wall mounted)	IAPMO certified. Water saving up to 42%	188 mm (7.5") long swivel spout	Rs. 2,850/-	
Wash Basin	CERA	CARGO - Wall hung wash basins with full pedestal	IAPMO certified.	Pedestal – Ht.- 830 mm 550 x 480 x 220 mm	Rs. 4,540/-	
Health Faucet	CERA	Health Faucet POM body and braided hose pipe	IAPMO certified. Water saving up to 80%	1.2-meter-long hose pipe	Rs. 1,465/-	

Table 16: Efficient Plumbing fixtures used

Two types of storages are required, over-head for distribution and underground storage tanks for treatment and storage. The purpose and capacity of the tanks have been listed in table 17.

	Storage Tanks	Capacity (L)
Over-head water Tank	Potable Water Tank	30,000
	Water tank for flushing	10,000
	Fire-safety Tank	25,000
Underground Water Tank	Borewell Tank	60,000
	Grey water Tank	20,000

Table 17: Capacity of Storage Tanks

Landscape Design

Objectives:
1. Use of native plants and trees, adopting xeriscaping technique for landscape design
2. Optimize the provision of grass area and strategically designing softscape and hardscape surfaces.

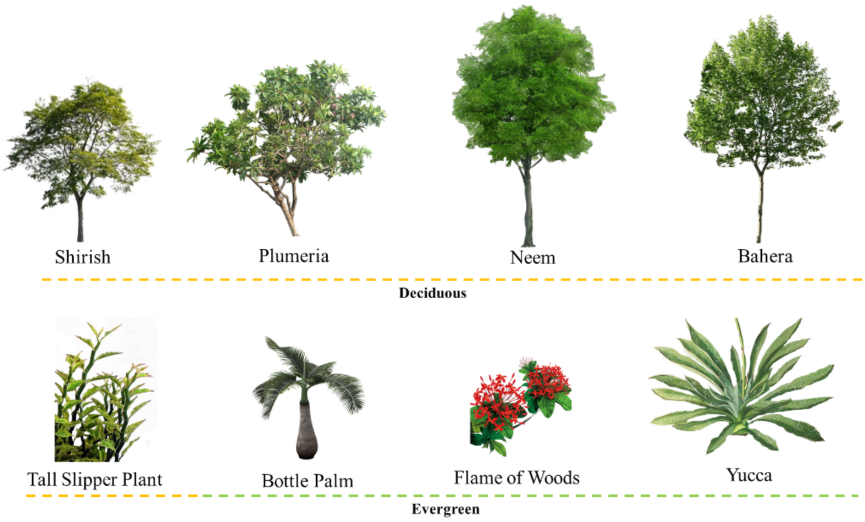


Figure 24: Trees and Plants used for Landscaping

Xeriscaping

Xeriscaping is the process of landscaping, that reduces or eliminates the need for irrigation.

Why xeriscaping?

It saves water and money. Not only does it save water and money, but a well-designed xeriscape is easier to maintain because it works within a framework that is consistent with local energy
The above figure shows Trees and Plants used for Landscape design that require less water for irrigation and are available in the local context.

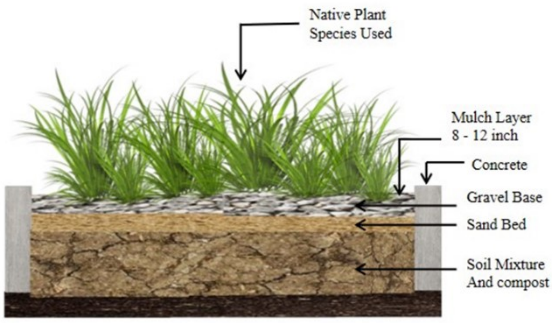


Figure 25: Section showing layers of Mulching

The process of Mulching

Mulches are blankets of loose material that cover the soil to minimize evaporation, keep roots cool in summer, suppress weed growth and slower soil erosion. Mulches can also provide visual interest and make the landscape more cohesive until young plants mature to fill the space.
Just two to four inches of mulch can substantially retain soil moisture, slow evaporation, and protect roots from overheating. Organic mulches are used in our design such as straw, bark chips, dry leaves, wood dust and shredded hardwood, which are the best choices because they retain moisture and add nutrients to the soil as they decompose.

Irrigation strategies

There are two types of irrigation strategies that are incorporated.
1. Sprinkler system
2. Drip Irrigation

Sprinkler System

Rain Bird's 12SA Rotary Sprinklers provide highly uniform water distribution. The sprinkler produces remarkably low precipitation rates of 0.6 in. per hour, reducing water use up to 30 percent. Efficient watering that reduces potential run off. The 12SA nozzle's water droplets are larger than traditional sprinkler droplets, resisting windblown overspray.
Installation - The 12SA is easy to adjust: simply use a standard slotted screwdriver to adjust the throw distance (radius range) from 13 to 18 ft and with 4-in. pop-up height. A water-lubricated rotating stream operation that's quiet and maintenance-free.
Coverage pattern - The 12SA Rotary Sprinkler is available in full- and quarter-circle patterns.

Drip Irrigation

Precise, low-volume watering at the root zone.
It uses micro watering devices placed near each plant. It installs easily on the surface without digging.
Rain Bird - 1/2" Sub-Surface Emitter Tubing Drip Irrigation.
It can be laid above or below ground and has 90% watering efficiency. 50ft coil waters plants evenly with 33 pressure-compensating 0.9 GPH emitters spaced 24in apart. It is faster and a more convenient way to make drip connections. Strong compression fitting avoids leaks.

Following Plans in figure show irrigation layout for the proposed landscape design.

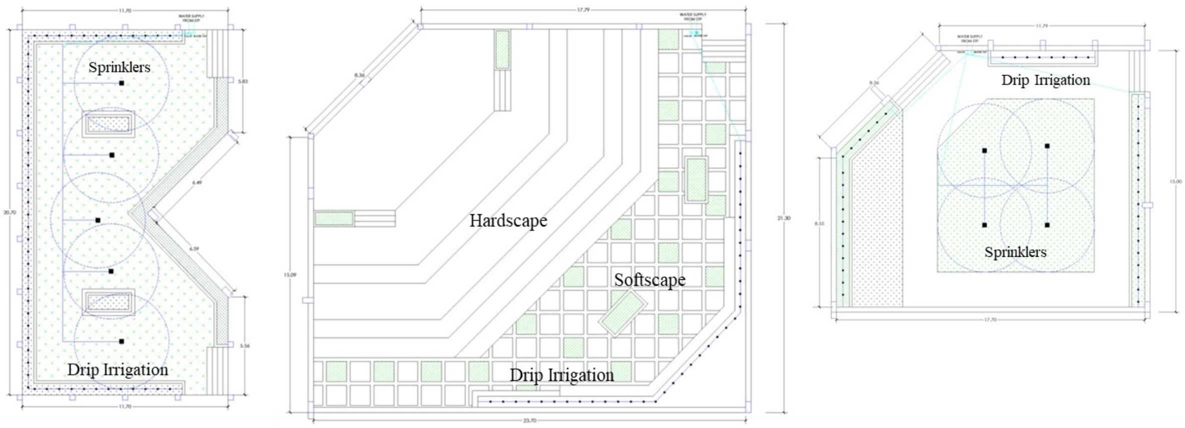


Figure 26: Plans showing Irrigation Layout with combination of Sprinklers and Drip Irrigation

Other strategies that help in rainwater collecting and harvesting

Rain water harvesting is done in one of the courtyards by the means of channels created and carved out of columns. Columns with channels allows water to seep into the vegetation as shown in figure 27. To ensure maximum collection of rain water from the roof top directly into the courtyard, these hollow slit columns are used. Strategical placement of planters, beside the columns helps to percolate water inside the plant roots directly without using any mechanical system.

Figure 27: Section showing designed columns with channels

Type of softscape and hardscape are also a factor that determine the amount of rainwater harvested or the amount of groundwater recharged (Refer Fig 28)

Figure 28: Detailing of Softscape and Hardscape provided

Figure 29 shows details of the softscapes and the hardscapes used in each open pocket with their run-off co-efficient to analyze the water performance of the designed landscape.

Spaces	Landscape	Area (sq m)	Run - off coefficient	Total Area (sq m)	Material
Courtyard 01	Hardscape	96.62	0.75	72.5	Permeable Tile
	Softscape	141.055	0.25	35.26	Turf grass
Courtyard 02	Hardscape	14.77	0.75	11.07	Gravel
	Softscape	186.5	0.25	46.62	Turf grass
OAT	Hardscape	432	0.75	31.665	Gravel
			0.95	370.5	Concrete Tile
	Softscape	57	0.25	14.25	Turf grass
Parking	Hardscape	1000	0.75	750	Permeable Tile
	Softscape	353	0.25	88.25	Grass
Total Area for Harvesting				1420.115	Sqm

Figure 29: Run-off coefficient of the provided landscape

Storage and treatment of water:

S. No.	Parameter	Raw Effluent	Treated Effluent
1.	Daily Average flow	40 KLD	40 KLD
2.	pH	6.5-8.5	6.5-8.5
3.	Total suspend solids	1000-1200 mg/l	<10 mg/l
4.	Total BOD	300-250 mg/l	<10 mg/l
5.	Total COD	450-500 mg/l	<30 mg/l
6.	Oil & grease	<10 mg/l	NIL

Water will be stored based on purpose and treatment required. Capacity and location of all water tanks have been shown. (refer table). Grey water will be treated to reuse it for various purposes like landscaping and flushing.

Sewage Treatment Plant Details

The wastewater treatment plant is designed to treat 40,000 Ltr/Day Sewage generated from Unit. The treated effluent will be used for gardening & horticulture.
For a maximum of 840 users Capacity of STP = 40 KLD Characteristics of wastewater:
The Wastewater characteristics considered for the design purpose of the plant is as mentioned in following table.

MSEP FABRICATED BASED STP				
Items	**MOC**	**Tank Volume**	**Sizes in CUM**	**Qty.**
Screen Chamber	RCC	0.5 M3	1L x 0.5W x 1D	1 No.
Oil & Grease Chamber	RCC	0.5 M3	1L x 0.5W x 1D	1 No.
Equalization Tank	RCC	10 M3	2L x 2W x 2.5D+0.2FB	1 No.
MBBR Tank	MSEP	15 M3	3L x 2W x 2.5D+0.2FB	1 No.
Settling Tank	MSEP	5.0 M3	1L x 2W x 2.5D+0.2FB	1 No.
Filter Feed Tank	MSEP	7.0 M	1.4L x 2W x 2.5D+0.2FB	1 No.
Treated Water Tank	RCC	5.0 M3	1L x 2W x 2.5D+0.2FB	1 No.
Sludge drying bed	Bricks	6.0 M3	As Per Design	1 No.

Table 18: Details of STP

c. Resilience

The project addresses resilience to heat waves, UHI effect for future climate change and other natural and manmade calamities in the following ways.

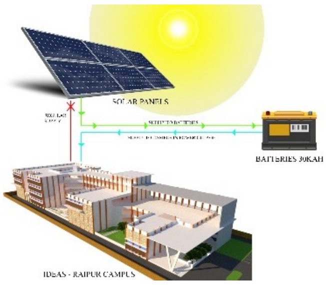


Figure 30: Resilience Against power outage

Resilience against Power Outage

Rooftop is provided with batteries having potential to supply electricity to the building during electricity cut-off resulting from extreme weather conditions or other emergency situations. The batteries are powered with Roof top Photo Voltaic System. The building also is provided with DG set in basement which would run on green fuels. The adopted systems will avoid the electricity disruption to a major extent and will assist seamless operation of the infrastructure.

Resilience against Floods

Creating a raised level up to 0.9m would help in preventing water seepage on plinth level. This strategy is provided to the tackle the possibility of floods.
Provision of the permeable surfaces i.e., the surfaces as a landscape design strategy, providing green areas, pebbles and gravels allow water to pass through and percolate into the ground. This would help in recharging and managing ground water levels.

Resilience against Water Outage/Drought

The structure includes an emergency reservoir and has an installed emergency pump station, where stored water inside reservoir is transferred into the water supply infrastructure of the building in situations of contingency.

Exterior Shading Device

Figure 31: Shading Devices

Shading devices are an effective means to cut down on solar heat gain into the building and thereby reducing the external surface temperatures of the envelope. The strategy is not to reduce heat gain with compromising on daylighting, but to provide an optimum design of the shading device.

Resilience Against UHI effect

The building is thoughtfully designed with courtyards as pockets for ventilation allowing air to move through the building reducing the effect of urban heat island. As the known phenomenon of Urban Heat Island is majorly caused when the air is trapped in the dense building pockets increasing the temperature of micro-climate.

Cool Roof Tiles: Cool roof tiles control the transmission of heat from roof to the interiors of the building. These tiles are naturally reflective and aid in achieving cool roof standards.

Figure 32: Layers of Green Roofing

Green Roofs: Green roofs provide thermal comfort inside the building along with the other environmental benefits like storm water management, aesthetic value and better air quality. Green roof shades the building from the direct sun light and reduce both the inside temperatures and surrounding air temperatures through evapo-transpiration.

Fire Fighting System: Fire evacuation and sprinkler system has been designed for easy evacuation in situations of emergency fire. Details and evacuation plans are provided in the Appendix.

Early warning System

Currently Raipur comes under low occurrence to any disaster as per CSDMA. With the help of IMD & CSDMA, early warning will be generated in the city and dissemination of warning by all the above agencies is through formal mail/fax being sent to government departments.

d. Affordability

The building is proposed with conventional material and construction techniques. Selection of material is thoughtfully done considering the availability of material within radius of 300 km. Conventional construction techniques and structural system allows use of local resources in terms of material, construction technology, equipment and labor, thus ensuring the affordability.

Sr. No	Parameters	Conventional chilled water system	Radiant cooling +DOAS
1	Technology	The air is cooled by the chilled water supplied by chilling unit, pumps & other control system	The major sensible cooling is done by radiant & The latent load and minor sensible load is taken care by conventional system.
2	Brief system description	Conventional system with chiller, AHUs, chilled water piping, ducting, air terminals, etc	The 20mm dia PEX a pipes with suspended ceiling, the chilled water flowing through it will cool the ceiling surface providing radiant cooling.
3	Design temperature	The design temperature is maintained 23+/- 1 Deg C for comfort condition.	The design temperature is maintained 23+/- 1 Deg C for comfort condition.
4	Chilled water temperature	Chilled water is supplied at 7 & return at 12 Deg C to cool the air which in turn cools the conditioned area.	The chilled water is supplied at around 15 & return at 20 Deg C to cool the surface which in turn cools the conditioned area
5	Air side	The entire cooling is done by air at around 400 CFM/TR.	The radiant cooling surface reduces the requirement of air and only the sensible load not catered by radiant cooling will be addressed by air
6	Fan power	Very high power consumption at fan side as the entire cooling by circulation of air.	Around 50-60% reduction in fan power as the air circulation required is less
7	Chiller selection.	Chiller is selected for 7 & 12 Deg C inlet and outlet temperature.	the chiller can be selected for 15 & 20 Deg C, thus a smaller size chiller can be selected for the required TR
8	Duct size	Duct size and ducting quantity is large as the entire cooling is through the air	Ducting is drastically reduced due to reduced CFM by 50-60%
9	AHUs	No of AHUs & size of AHUs required is very large to handle large amount of air.	No of Ahus and size drastically reduced saving a large amount of space consumed by AHU rooms
15	Energy saving	VFDs, VAVs and control system with proper co-ordination is used to achieve saving on the air side. Further, VFD driven chillers are used on chiller side to achieve max. power saving	Using a hybrid system with radiant cooling and conventional system, there is a power saving of around 25% from the very efficient conventional system
18	Connected load	40 - 50% of the building electric connected load is for the air conditioning system	The connected load will drastically reduce due to lesser AHUs, smaller size chiller for the radiant system.
19	AMC	Annual maintenance is required for large no of AHUs and VAVs	No AMC on the radiant side. Only a reduced conventional system to be taken care.
20	Operating cost per year	100%	20-25% energy cost saving from conventional system. Around 30% saving on AMC cost from conventional system.

Table 19: Comparison between conventional HVAC and Radiant Cooling

Design strategies for rightsizing and optimization operational cost

Radiant Cooling System

The building envelope is optimized for reducing heat gain by means of shading devices and passive techniques considering extreme seasons in composite climate of Raipur. For unmet thermal comfort hours, the radiant cooling system is proposed for air conditioned and mixed mode spaces. Though radiant cooling system is not conventional in India as of now, but has a potential to replace other HVAC systems due to its benefits in terms of quality, working as well as in terms of cost efficiency.
Table 19 shows a comparison between Conventional Chilled water system and Radiant Cooling system. The parameters of comparison talk about working, efficiency, energy savings, cost savings, etc.
The radiant cooling system when compared with conventional HVAC system shows that it is more efficient. In terms of costs, the table 21 shows that Radiant cooling system saves 12% of the total cost as compared to the conventional one. Thus, installation and components of radiant cooling system is more affordable and efficient. Details are provided in the Appendix.
Radiant cooling system is also efficient when it comes to energy performance, hence saving energy. A comparison of annual energy consumption by conventional Variable Refrigerant Flow and Radiant cooling system has been shown in table 22.
As the year progresses ahead, clear difference in the consumption is derived. Within 10 years, 25.6% reduction of the energy consumption is resulted as shown in figure 28.

Cost Comparism			
Sr.No	Components	VRF System	R.C System
1	Chillers (TR)	197	121
	Cost	₹80,00,000.00	₹40,00,000.00
2	Chilled water pump (gpm)	472.8	290.4
	Cost	₹2,36,400.00	₹1,45,200.00
3	Fan coil units (Qty)	78	59
	Cost	₹11,70,000.00	₹8,85,000.00
4	Ducting (m)	₹10,00,000.00	₹0.00
7	DOAS (TR)	197	121
	Cost	₹26,77,362.00	₹16,80,906.00
10	Radiant Panel And Ducting	₹0.00	₹50,00,000.00
Total		₹1,30,83,762.00	₹1,17,11,106.00
Reduced by		12%	
Savings		₹13,72,656.00	

Table 21: Cost comparison of VRF and Radiant Cooling

Annual Consumption		
Appliances	Radiant (Kwh)	Conventional (Kwh)
Chillers/cooling towers	74584.4	121430.8
DOAS	119600	165600
Chilled water pump (gpm)	1840	4416
Fan coil units	9641.6	11555.2
Total	205666	303002

Table 23: Energy consumption calculation

	TR	Year - 01	Year - 02	Year - 03	Year - 04	Year - 05	Year - 06	Year - 07	Year - 08	Year - 09	Year - 10
Installation of Radiant Cooling + DOAS	121	41299.2	82598.4	123897.6	247795.2	495590.4	867283.2	1734566.4	3097440	6194880	11026886.4
Installation of Variable Refrigenrent Flow+DOAS	197	55555.2	111110.4	166665.6	333331.2	666662.4	1166659.2	2333318.4	4166640	8333280	14833238.4

Table 20: Investment comparison

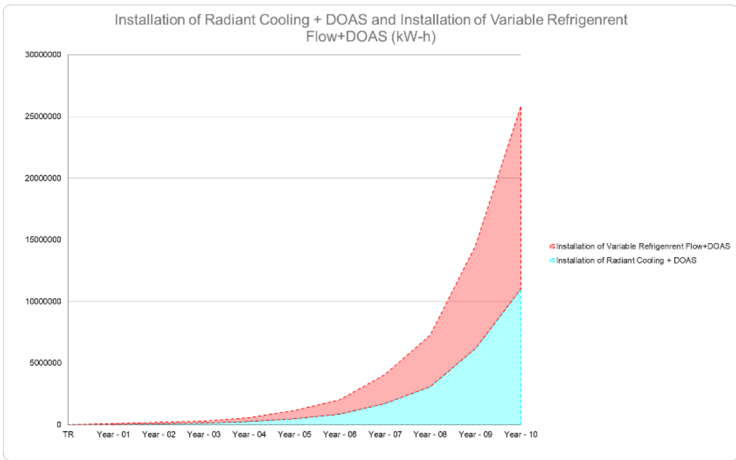


Figure 33: Return of Investment Comparison Chart

	Year - 01	Year - 02	Year - 03	Year - 04	Year - 05	Year - 06	Year - 07	Year - 08	Year - 09	Year - 10
Installation of Efficient Electrical Appliances (KWH)	179062	358124	537186	1074372	2148744	3760302	7520604	13429650	26859300	47809554
Installation of Convnetional Electrical Appliances (KWH)	400000	800000	1200000	2400000	4800000	8400000	16800000	30000000	60000000	106800000

Table 22: ROI comparison for conventional and efficient electrical appliances

b. Efficient Electrical Appliances

Electrical appliances play a major role in the entire functioning and costing during the operational phase of a building. Efficient appliances reduce energy consumption and hence, the capacity of solar generation plant required will also be minimized. The following table 23 and figure 29 show comparison of return of investment of installing conventional and efficient electrical appliances.

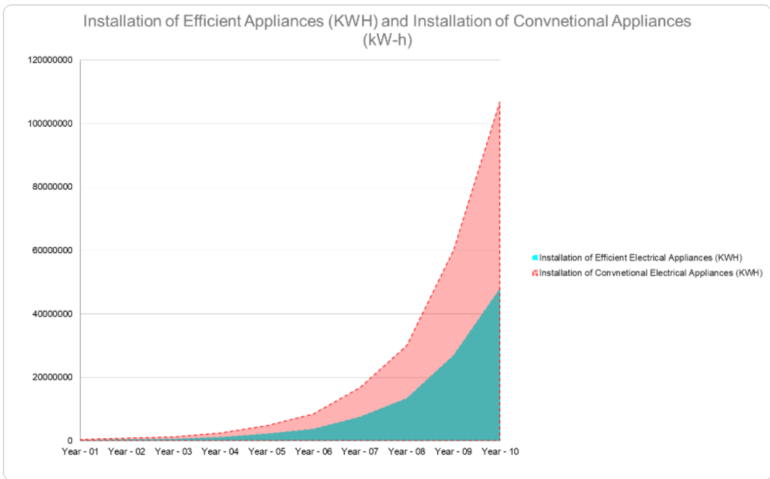


Figure 34: ROI Graph showing comparison of energy consumption by conventional and efficient electrical appliances

c. Solar Generation System
(Return of Investment)

The following table 24 and figure 34 show investment required for Solar generation system and Return of Investment has been analyzed.

	One Time Investment	Yearly Investment	Year - 01	Year - 02	Year - 03	Year - 04	Year - 05	Year - 06	Year - 07	Year - 08	Year - 09	Year - 10
Solar Panel Installation Investment	16000000	150000	150000	300000	450000	600000	750000	900000	1050000	1200000	1350000	1500000
Conventional System Investment	8155000	1500000	1500000	3000000	4500000	6000000	7500000	9000000	10500000	12000000	13500000	15000000

Table 24: ROI for solar generation system and conventional system

The solar generation system is compared with conventional energy systems and it can be seen that solar generation system requires a higher initial investment but the total cost is recovered over a period of time.

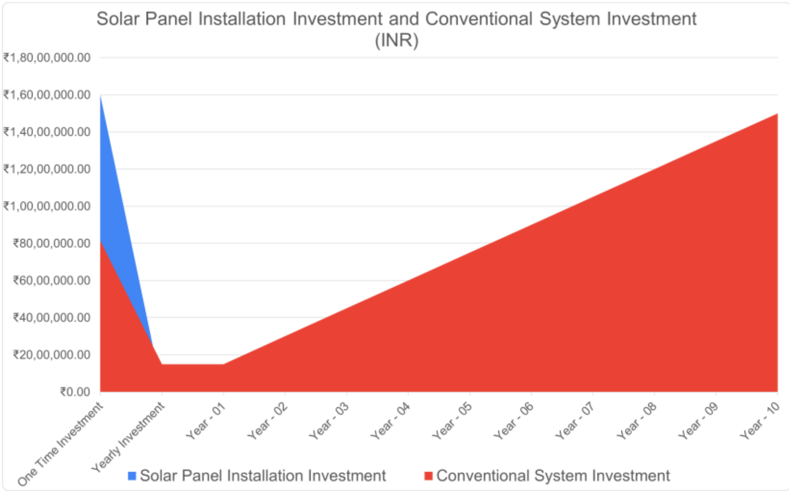


Figure 35: ROI comparison graph

Phase Wise construction

According to the requirement of the Project partner, the proposal has been divided in 3 phases of construction to ensure feasibility and reduce one time investment. Thus, only the required area program would be constructed in the first phase according to the intake of students and number of other users. The details of phase-wise construction are provided in Appendix.

e. Innovation

Innovation as thought by the team has been projected as a solution for problems at site as well as building level. The problem identified are existing issues as well as problems that are assumed to be faced in the near future.
In composite climate zone, due to varied climatic conditions and different seasons, the thermal comfort requirements are different for different months. This calls for a building design that is ready to mould itself for all kinds of seasons and conditions. Thus, solution for catering to changing thermal comfort requirements is to design a simultaneously changing building element.
This building element is developed as a kinetic façade which is dynamic and is responsive to the changing

weather conditions, majorly the solar radiation, daylight and wind. The objective of the kinetic façade is to operate on the sensors that detect solar radiation and the units open and close in response to the detected amount of radiation. It acts as a double skin of the building which can change its function and behavior over time to improve the overall building performance. This facade system can save energy by optimizing for different directions and orientations and support comfort levels by immediately responding to weather conditions.

This contest area in also looked at as an opportunity to improve the performance of other contest areas such as Comfort and Environmental Quality, Energy Performance and Architectural Design. Thus, Kinetic façade is designed as a response to provide thermal comfort. It also improves energy performance as it reduces cooling demand, in turn reducing a significant amount of energy consumption. Aesthetically, Kinetic façade is composed with vertical slanted louvres and daylight shelves to give a dynamic looking façade as shown in figure 33.

Development of Kinetic Façade

The design of kinetic façade is developed by considering a unit module which is in response to the structural grid of the building. A single unit is developed such that it can be repeated, scaled in size and also optimized for different directions and orientations. Different geometries were explored and analyzed to develop a form that is best suitable to respond to the requirements of the façade. The following figure 38 shows process of development of form of a single unit of the kinetic façade.
The kinetic Façade provide shading to the façade during summers and is optimized to allow solar radiation during winters.

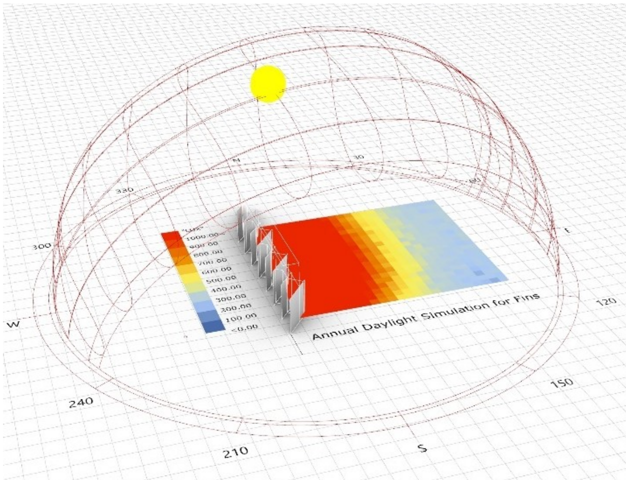


Figure 36: Daylight simulation with fins

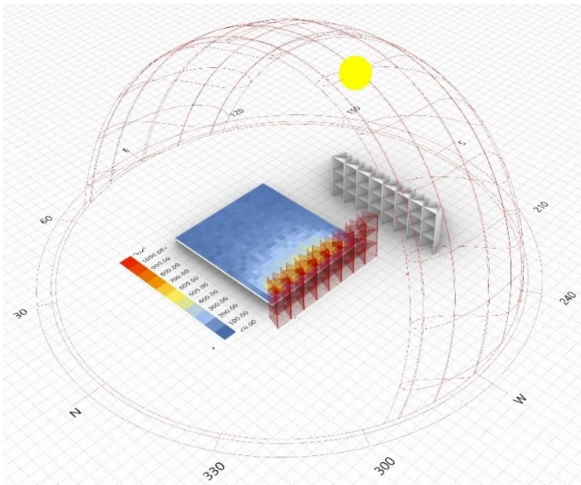


Figure 37: Daylighting simulation of kinetic facade

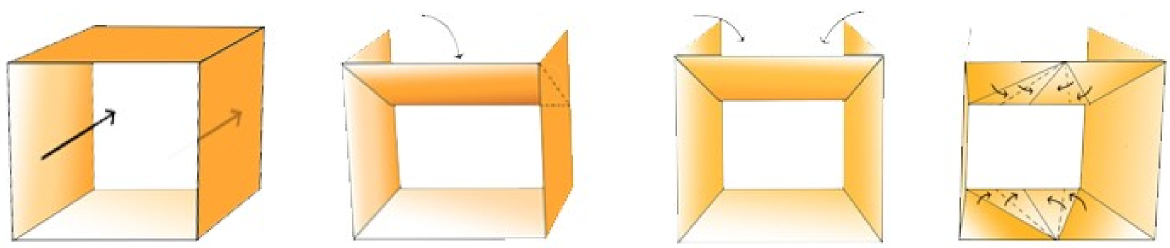


Figure 38: Process of Development of Kinetic facade unit

The design of educational building has major problems of heat gains and glare which results in increase in energy consumption cost of HVAC. The unique features of the kinetic facade are thermal comfort, visual comfort in the interior spaces by the means of appropriate daylight and enhanced building appearance. The following figure 32 and 33 show simulation results of the kinetic façade when tested for daylighting with fins and with kinetic façade.

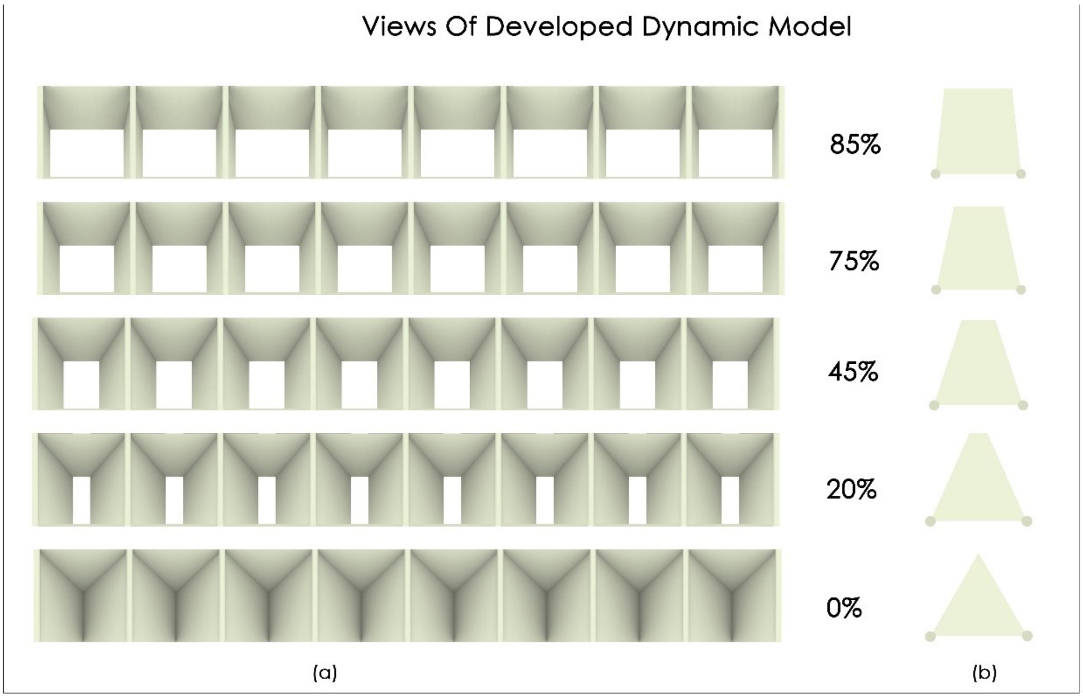


Figure 39: Simulation of kinetic facade showing amount of opening on sensor-based operation

In future, kinetic facades would be combined with Artificial Intelligence and IOT (Internet of Things) which would help to further enhance the energy performance of the kinetic façade. The basic concept of AI and its working is provided in the Appendix.

*The proposed kinetic façade is thoroughly discussed with Industry Partner for its feasibility and cost has been worked out accordingly.

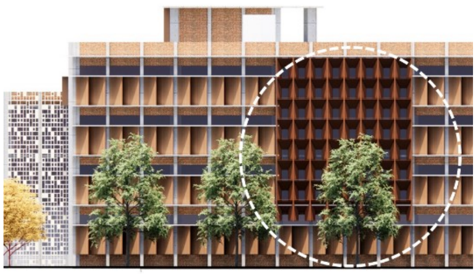


Figure 40: View of Kinetic Facade in Elevation

f. Scalability and Market Potential

The team has worked on a building proposal that has potential to scale up two major systems namely, Kinetic Façade and Radiant Cooling.

Kinetic Façade

Kinetic façade as a product targets and can cater to many building typologies such as Institutional, Commercial, Residential, Health facilities, Industrial, etc.

The dimensions of a single module of the kinetic façade are repetitive in nature and allows multiple modules to set as per the size of the façade. The module allows it to use for allowance and restriction for solar radiation, wind and daylight. Hence, can be used for the requirement of any one or all three elements and its control in the building.

The kinetic façade is easy to develop for a manufacturer due to its flexibility in terms of selection of material and simple manufacturing details. These modules can also be used as static facades in case of requirement of venturi effect as demonstrated in the screen of the courtyard of proposed building. The proposed building itself becomes a display of the workability of the kinetic façade to reach out to the public and end users to increase its market potential. Details are shown in Figure 41.

Sr.No	Image	Assembly	Material	Size of member	No of Member in single unit	No of units in whole façade	Cost /m2 or running m	Total cost
1		Pyranometer Sensor	….	…..	1	4	₹17,160.00	₹68,640.00
2		Supporting vertical Pipes	Aluminum	50mm,Length=2M	2	386	₹197.00	₹1,52,084.00
3		Framing	Aluminum	25x25mm,Length= 4.6M	4.6	887.8	₹130.44	₹5,32,701.31
4		Thickness Sealed Deep Groove Ball Bearing	Steel	26mm OD 10mm, Inner Dia 8mm	2	386	₹820.00	₹6,33,040.00
5		FRP Panels	Fibre-reinforced plastic	3000mmX1500mm	1	193	₹820.00	₹1,58,260.00
6		750N Electric Actuator	…..	…...	2	386	₹12,259.00	₹94,63,948.00
Total							₹31,386.44	₹1,10,08,673.31

Figure 41: Details of Kinetic Facade

Radiant Cooling

Radiant cooling is a less known HVAC system in India, in spite of its efficiency in terms of energy performance. The use of this system in the proposed building will create awareness and provide an understanding and confidence to incorporate this system in future building designs. Refer figure 42 for details.

This creates market potential to agencies, industries and manufacturers of radiant cooling and the product can be scaled up to the maximum potential. The details of proposed radiant cooling system are provided under Energy Performance and Engineering Design section.

Cost Details of Radiant Cooling		
Sr.No	Components	R.C System
1	Chillers (TR)	121
	Cost	₹40,00,000.00
2	Chilled water pump (gpm)	290.4
	Cost	₹1,45,200.00
3	Fan coil units (Qty)	59
	Cost	₹8,85,000.00
4	Ducting (m)	₹0.00
7	DOAS (TR)	121
	Cost	₹16,80,906.00
10	Radiant Panel And Ducting	₹50,00,000.00
Total		₹1,17,11,106.00

Figure 42: Costing Details of Radiant Cooling

g. Comfort and Environmental Quality

This contest area opened up opportunity to explore and experiment with different building elements and configurations. The psychrometric chart in figure 37 shows number of comfortable hours and strategies to beused to achieve them.

Thus, comfortable hours = 71%
Hours of discomfort = 29%
Therefore, mechanical cooling would be required for rest of the time. But major thermal comfort can be provided by applying the following strategies.

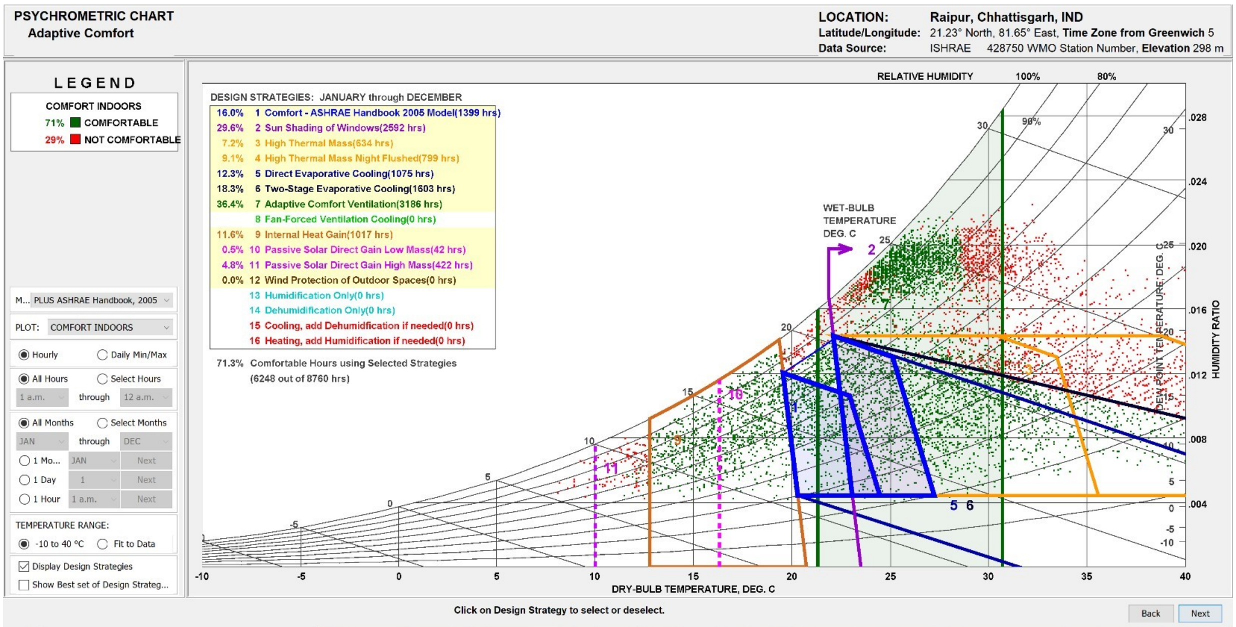


Figure 43: Psychrometric Chart

Building Type	Glazing Gains (kW)	Wall Gains (kW)	Floor Gains (kW)	Roof and Ceiling Gains (kW)	Ventilation Gains (kW)	Infiltration Gains (kW)	Electric Equipment Gains (kW)	Lighting Gains (kW)	People Gains (kW)	Solar Gains (kW)	Total Gains (kW)
Conventional	-60.21	-52.13	-202.74	63.55	72.61	-58.93	53.42	143.18	37.12	480.1	475.97
With Material	-49.52	-103.11	-167.86	-45.66	74.91	-41.5	55.88	150.41	38.24	477.5	389.29
With Material and Fins	-57.3	-96.75	-162.97	-37.28	75.36	-37.4	55.88	150.41	38.51	424.25	352.71

Table 25: Comparison of Envelope options with respect to heat gain sources

Use of slanted vertical louvres reduces glazing gain, wall gain and solar gain, reducing the total heat gain by 123.26 kW.

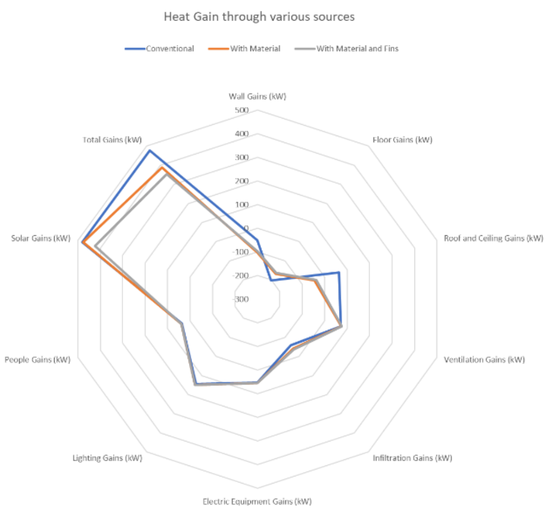


Figure 44:Comparison of Envelope options with respect to heat gain sources

The team has tried to design an institute that provides thermal comfort and maintain the environmental quality. It addresses issues of thermal and visual comfort and thus, strategies to provide the same have been incorporated.
The following is a list of passive design techniques that are used to achieve thermal and visual comfort.

a. Shading devices – Fins
b. Daylighting shelves
c. Courtyards
d. Stack effect
e. Downdraft System
f. Venturi Effect

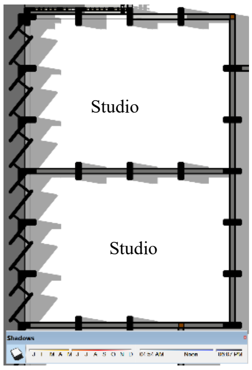


Figure 46: Shadow patten due to fins during Summer month

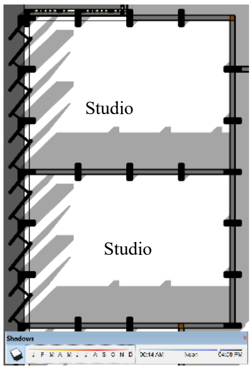


Figure 45: Shadow pattern due to fins during Winter month

Shading Device - Fins

Fins are a component of façade that are slanted vertical louvres designed to optimize for reducing solar heat gain. These are constructed in brick and compliment with the structural system that is proposed.

The figure 38 and 39 shows comparison of shadow pattern that is achieved during summer and winter.
One of the major objectives of designing these fins was to obstruct direct solar radiation in summers and allow sun during the winters. Hence, same can be inferred from the comparative analysis done through the shadow analysis in the figure 44 and 45.

The angle of the fins is decided by analyzing the azimuth angle. Depending on the azimuth angle the fin length, size, spacing and angle of inclination of the fin can be derived. Figure 40 shows detailed design of the fin showing opening, angle of inclination and the structural columns.

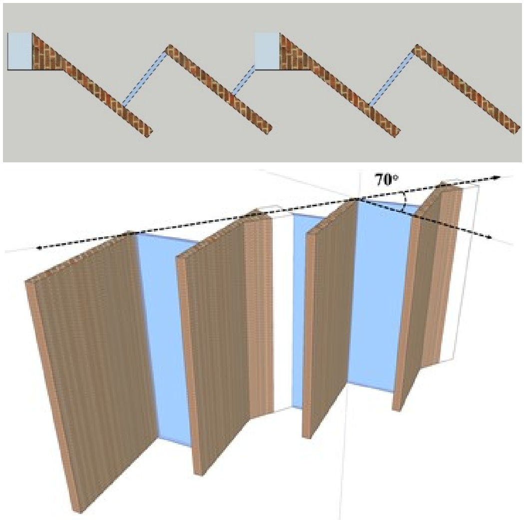


Figure 47: Details of Fins

ii. Daylighting Shelves

Objective of the daylight shelves was to increase daylight in the studios. As per NBC standards, the lux required for working in studios is 300-700 Lux.
With the provision of Inclined fins, there is a decrease in the amount of daylight that is achieved. An optimization for reducing solar heat gain and maintain the standard lux levels was required. Thus, daylighting shelves were designed to reflect sunlight more deeply into the studios. (Refer figure 47)

The analysis shown below compares daylighting simulations in 3 cases. Provision of daylighting shelves increase the daylighting intensity in the studios and hence the entire façade is optimized for reducing solar heat gain and providing optimum daylight. Refer figures 13-14-15.

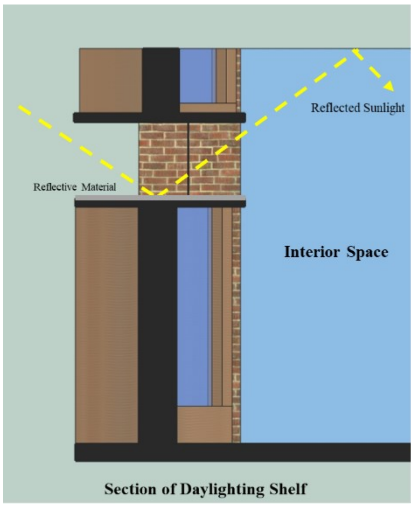
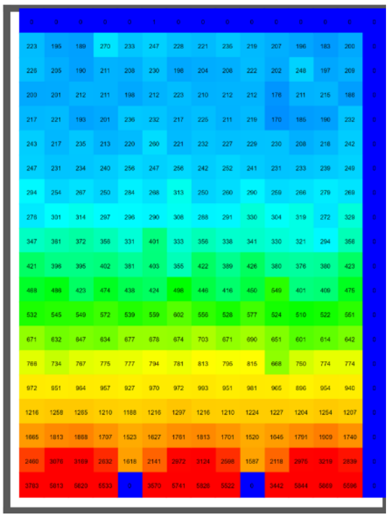


Figure 48: Section showing working of daylighting shelf in studios

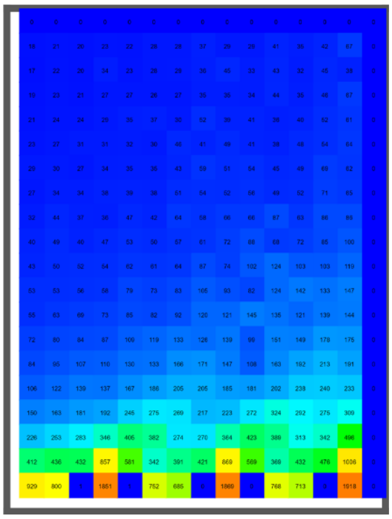


A. Conventional Opening

Good reach of light but glare can be witnessed near openings and can increase heat gain.

Average light at last gridline – **217.5 Lux**

Figure 13: Daylight simulation for conventional openings

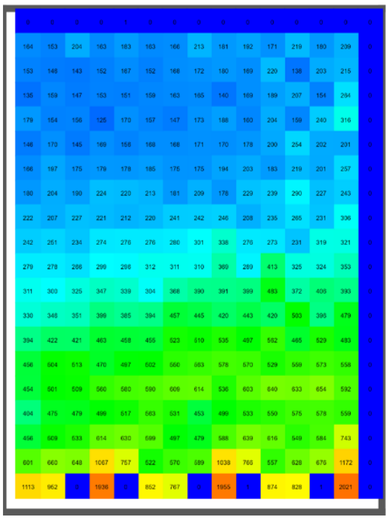


B. Vertical Openings and Fins

Introduced fins to reduce heat gain but it reduced daylight as well.

Average light at last gridline – **31.4 Lux**

Figure 14: Daylight simulation for Fins



C. Vertical Fins with Daylighting Shelves

Daylight shelves used above fins to increase daylight reach.

Average light at last gridline – **182.9 Lux**

Figure 15: Daylight simulation for fins with daylighting shelves

iii. Courtyards open spaces as micro-climate regulator

Courtyards are provided to facilitate cross ventilation throughout the building. According to the climatic data of Raipur (Appendix), one of the major challenges is to tackle humidity by providing wind movement during monsoon season. Thus, open pockets in the entire building configuration are composed in such a way that it allows movement of wind. The major wind direction of monsoon winds is from the South-west and thus the orientation and location of the courtyard is decided accordingly.

The geometry of the open pockets is designed to incorporate venturi effect, i.e., larger edge that captures the wind and a smaller edge that facilitates venturi effect. The figure 489e shows CFD Simulation of the building configuration. The open pockets can be seen as capturing the wind and there is cross ventilation that provides comfort to the users while occupying the open and semi-open spaces in the institute.

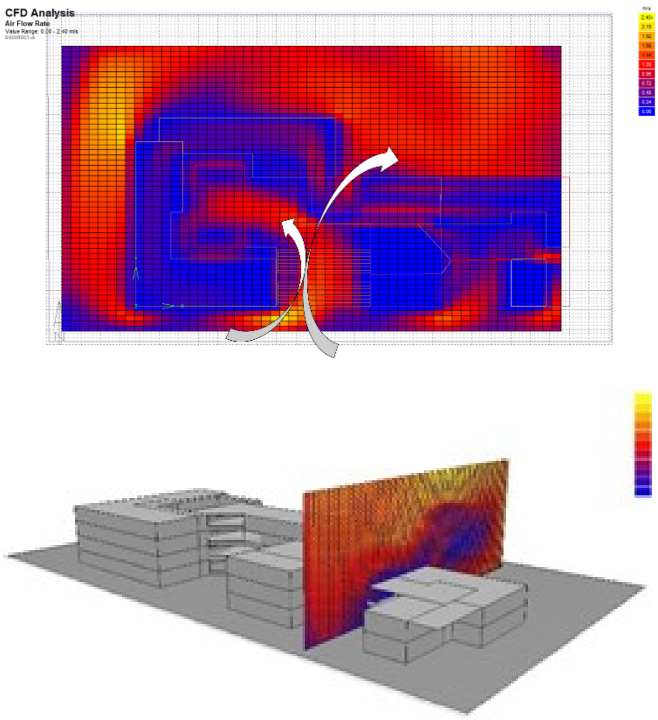


Figure 49: CFD simulation showing cross ventilation and venturi effect

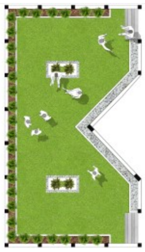
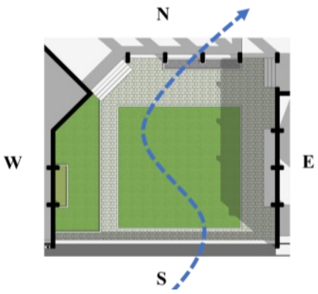
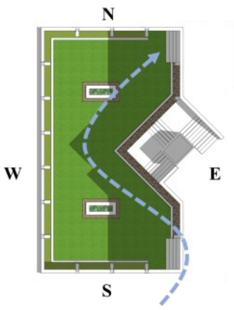
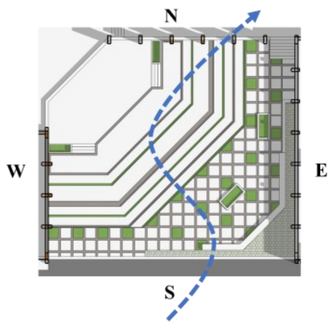
Specific list of courtyard design variants			
Open Spaces			
Configuration	Square\irregular	Rectangular	Square\Irregular
	3 sided enclose	Fully enclose	3 side enclose
Orientation	East - West facing South side	North - South	East - West facing South side
			
Shading Device	Overhangs and cantileverd roof creates shade	Shadow is cast by the diagonal staircase block placed at one of the courtyard edge	Over head Shading
Natural Features	Vegetation	Vegetation, Water Channel	Vegetation
Usage	Day lighting	Day lighting	Day lighting
	Ventilation	Ventilation	Ventilation
		Informal Activity	Recreational Activity

Figure 50: Details of Design of Open spaces

All the three open spaces are designed in a way to fulfill the needs of microclimate with respect to their seasonal changes. These requirements fulfilled with landscape design considering the factors to attain cross ventilation, evaporating cooling and for reducing solar heat gain. Landscaping is an important element in altering the microclimate of a place. It reduces direct sun from striking and heating up the building surfaces. It will also prevent reflected light carrying heat into a building from the ground and other surfaces. Refer figure 49 for detailed design process of open spaces.

iv. Shading Design for Open Air theatre

The Open-Air theatre (O.A.T) acts as a spill over space for informal activities. The objective of designing shading device is to obstruct summer sun and allow solar radiation during winters and ensure thermal comfort.

The design of the shading device above O.A.T is such that the objective is achieved. Shadow analysis of summer and winter has been shown in figures 50.

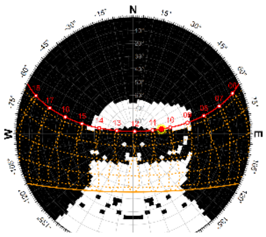


Figure 52: Shading mask for O.A.T

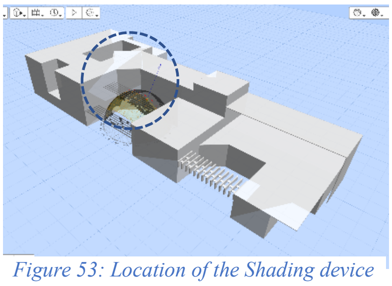


Figure 53: Location of the Shading device

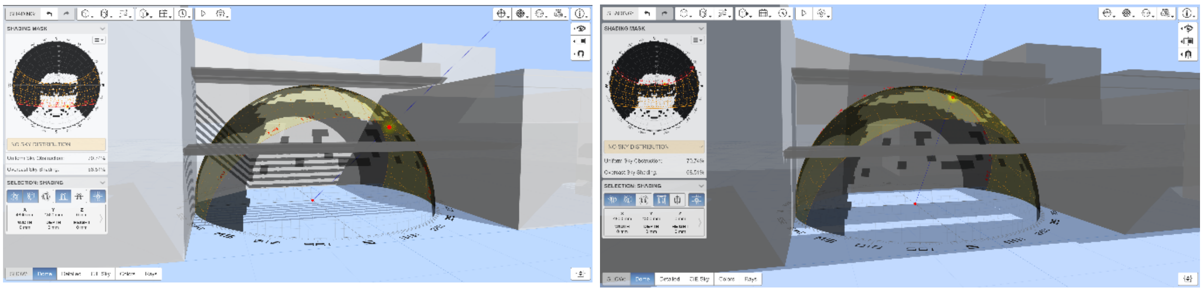


Figure 51: Shadow pattern due to shading in winter and summer respectively.

After Identifying the wind and shadow patterns of all the major seasons, the design process evolved with the help of these parameters. Position of soft and hardscape is determined according to the different seasons which effect the thermal comfort of the building. Vegetation is a flexible controller of solar and wind penetration in buildings. It reduces direct sun from striking and heating up building surfaces and lowers the outside air temperature which in turn effects the heat transfer from outside to building envelope and interior. The main goal is to optimize summer hot winds and solar radiation. To cater this, plantation, shading mask and kinetic facades are provided at specific locations to ensure the objectives of reducing the sun exposure to the building

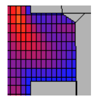
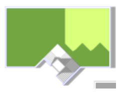
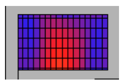
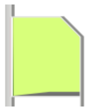
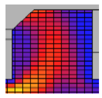
Spaces	Shadow pattern with respect to seasons			Wind pattern
	Summer	Monsoon	Winter	
Front Courtyard				
Rare Courtyard				
OAT				

Table 26: Shadow and Wind analysis

Downdraft System

Summer Outdoor Wet Bulb Depression (Dry Bulb Temp. – Wet Bulb Temp. (T_{db} - T_{wb})) – 18°C
Tower Height – 16.5 m
Air Flow Rate - 8 L/sec, m^2 of floor area
Inlet Area of Cooler Pads – 1.5% of floor area
Summer Outdoor Dry Bulb Temperature – 34 °C
Air Temp Out of Cooler - 20 °C
Cooling Rate expected - 80 W/m^2
Air flow Rate expected – 1.8 cfm/ft^2 of floor area
For Location of downdrafts refer Appendix.

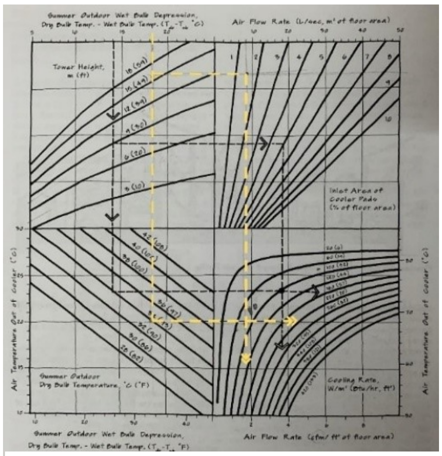


Figure 54:Sizing Downdraft Evaporative Cooling Towers: Sun Wind and Light

Composition of Façade

The façade has been composed according to the type of mode behind the façade. The mixed mode type space has a façade of kinetic double screen whereas naturally ventilated spaces have facade of slanted vertical louvres with daylighting shelves. The following figure shows process of composition of façade.

Figure 55: Process of composition of facade

v. Simulation results for hours of thermal comfort

The following graph in figure shows total annual hours of thermal comfort achieved without the use of radiant cooling and total annual unmet hours upon operation of the designed radiant cooling system.
Hence, Total unmet hours without Radiant cooling are _ and total unmet hours of comfort with provision of radiant cooling system is _.

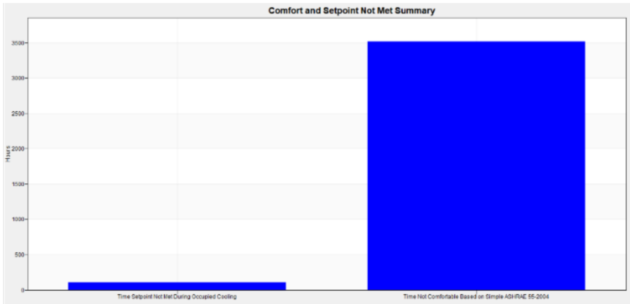


Figure 56: Unmet hours of thermal comfort with and without Radiant Cooling

Architecture

The goal of this contest area is to design a built-form that is a balance between open and closed spaces. An educational institute of such type needs to provide an inspiring and positive teaching and learning environment to the users. Thus, to provide such an experience following strategies were incorporated into the design.

1. One-Room Deep planning
2. Creating Courtyards
3. Spill over spaces for informal activities.
4. Changing volumes
5. Spaces that provide visual connectivity and enhance interaction

Following are the stages of development of basic built-form design.
Stage 1 – Basic 3D mass with foreground for circulation, parking and architectural appreciation.
Stage 2 – Defining locations of open pockets in response to the sun path and wind directions.
Stage 3 – Modulating the masses to create terraces as a strategy responding to the climatic conditions.
Stage 4 – Defining service core and final detailed block model

The open and built configuration results in creating spill over spaces for informal interactions.

A major feature of the design of the institute is the amalgamation of the built-form with the landscape and open space design. The landscape is designed to make open spaces adaptive to informal use and promote interaction.

Site Plan showing open-built relationship and site development. (For floor plan refer appendix)

Figure 57: Site Plan

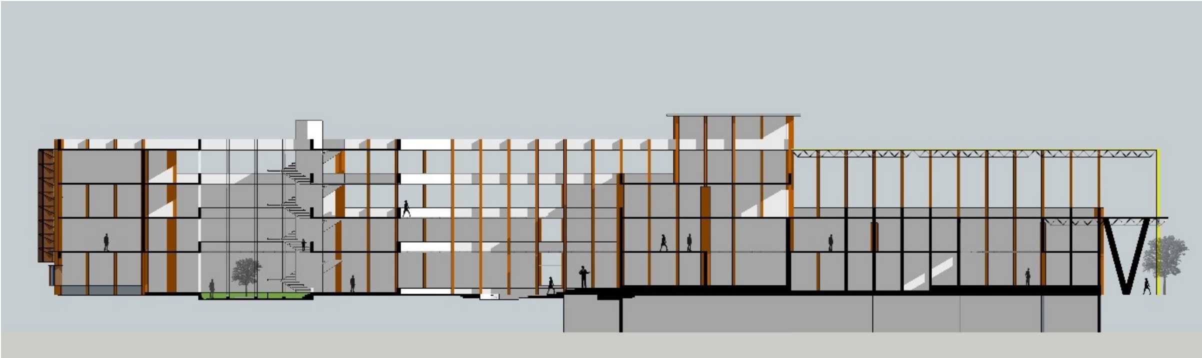


Figure 58: Section AA'

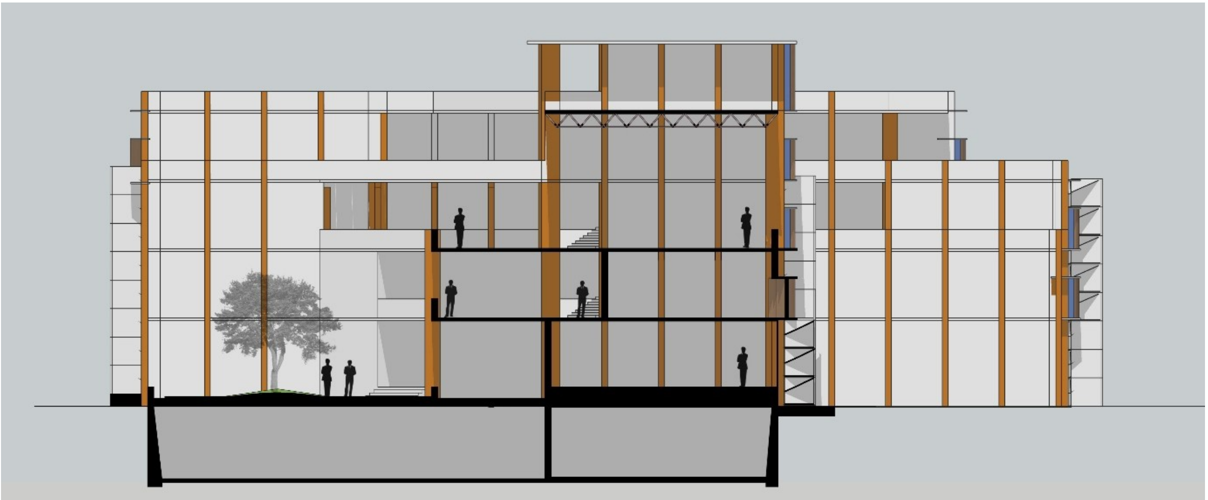


Figure 59: Section BB'

Figure 60: Front View

Elevations

Figure 61: South Elevation

Figure 62: North Elevation

Figure 63: East Elevation

Figure 64: West Elevation

Figure 65:Rendered' View

Figure 66: Rendered View

Engineering Design and Operations

Structural system

Structural System. The following figure shows center line plan of the building.

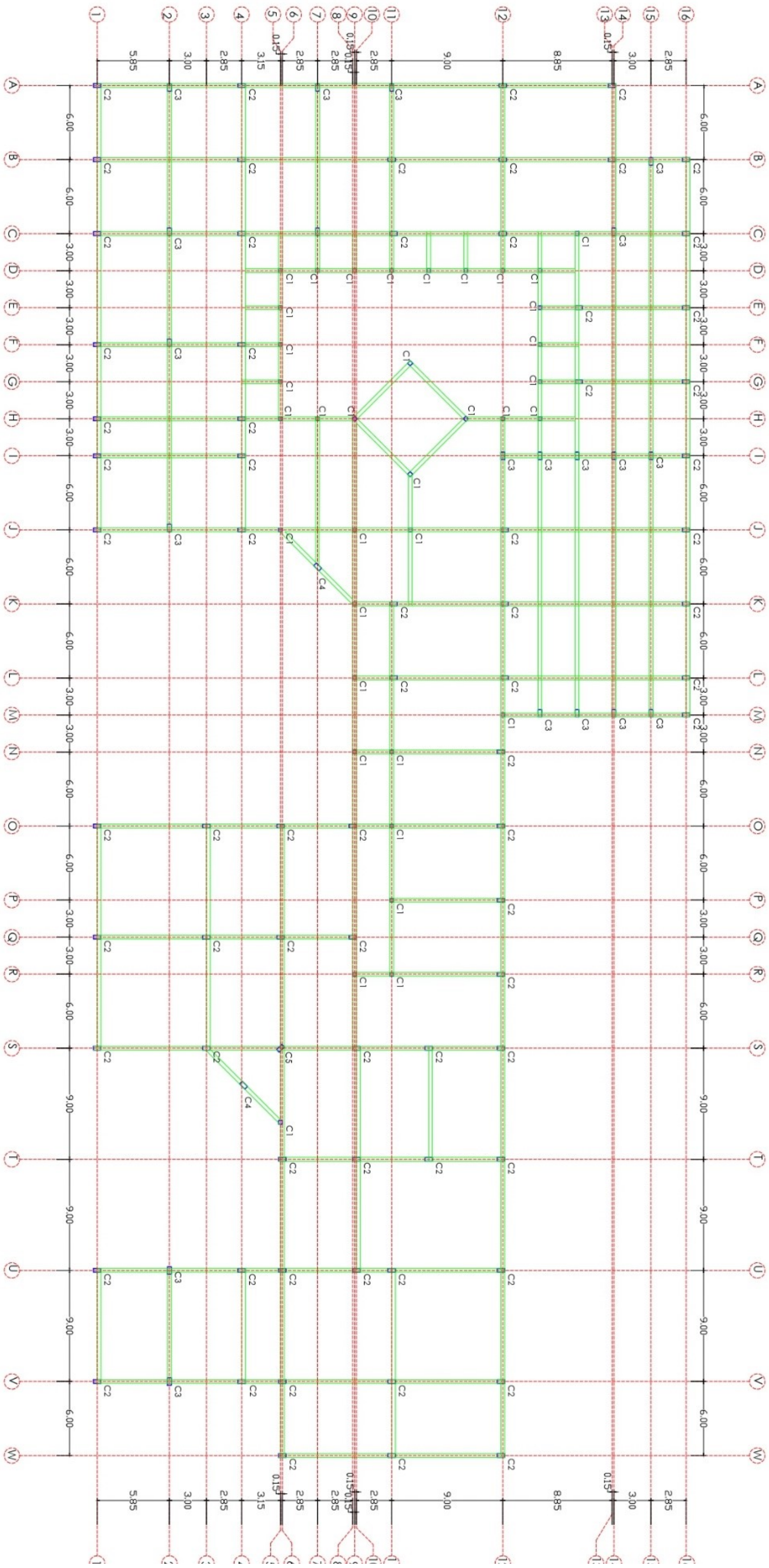


Figure 67: Centre Line Diagram

Schedule of Columns

Column Type

Sr. No.	Column Type	Dimensions in MM
01	C1	300X300
02	C2	300X600
03	C3	600X300
04	C4	300X600
05	C5	600X300

Beam Type

Sr. No.	Beam Type	Dimensions in MM
01	B1	300X450
02	B2	300X600
03	MB 1	300X600

HVAC Single Line Diagram

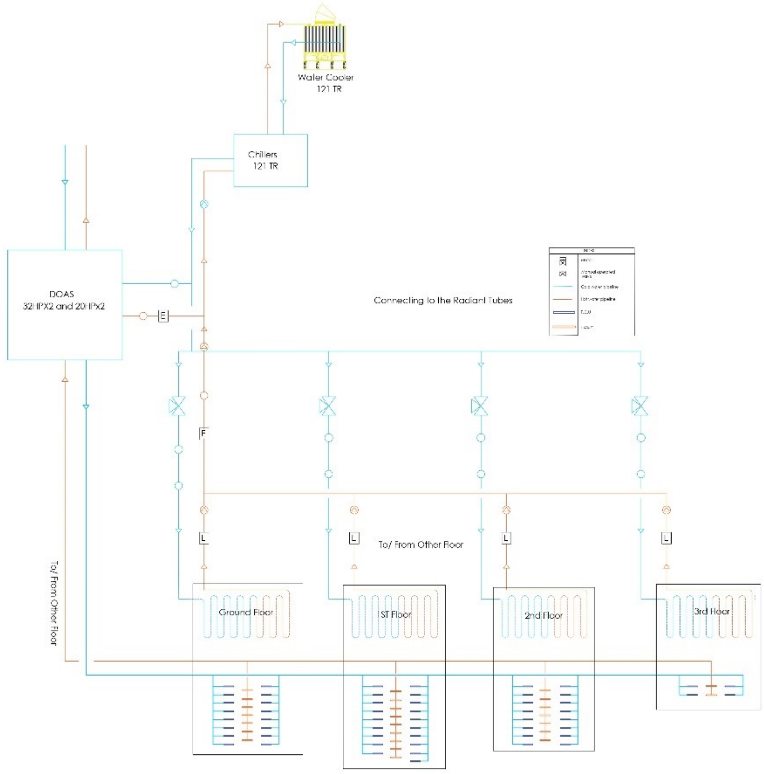


Figure 68: HVAC SLD

Electrical SLD

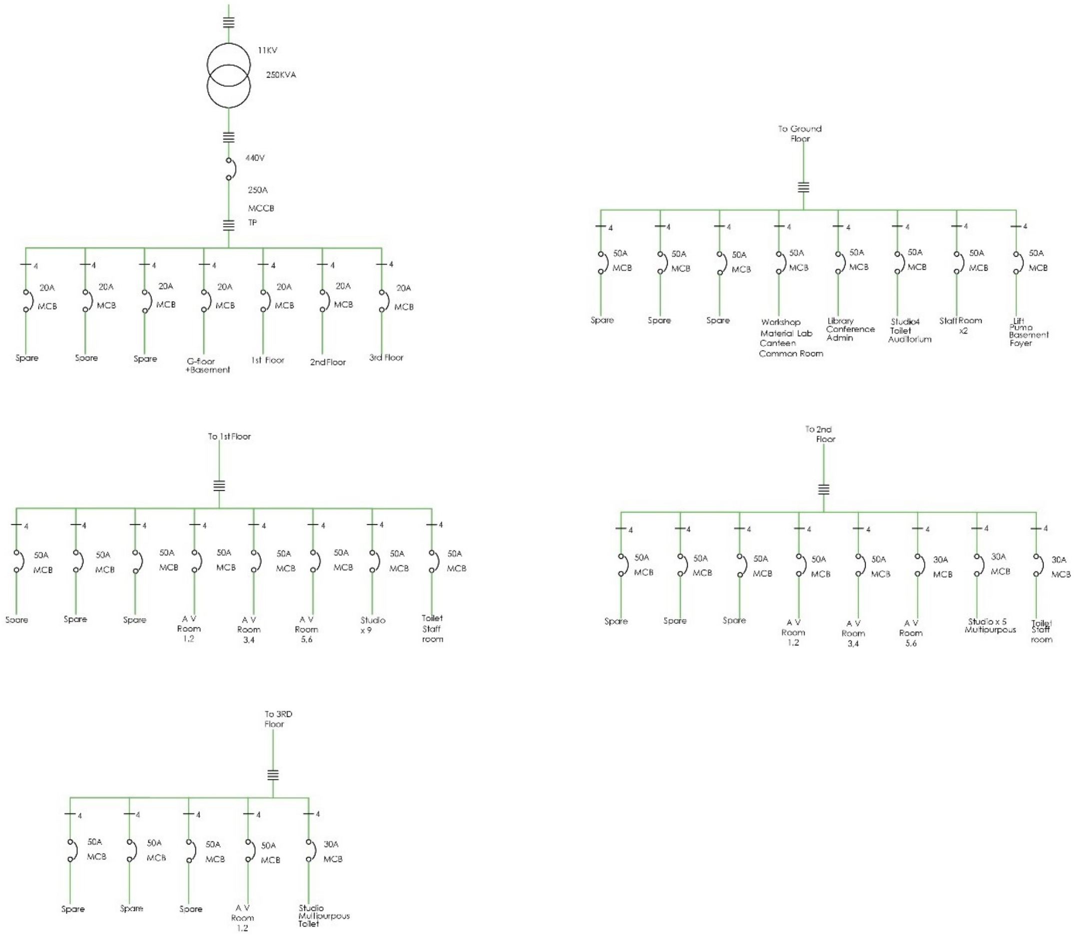
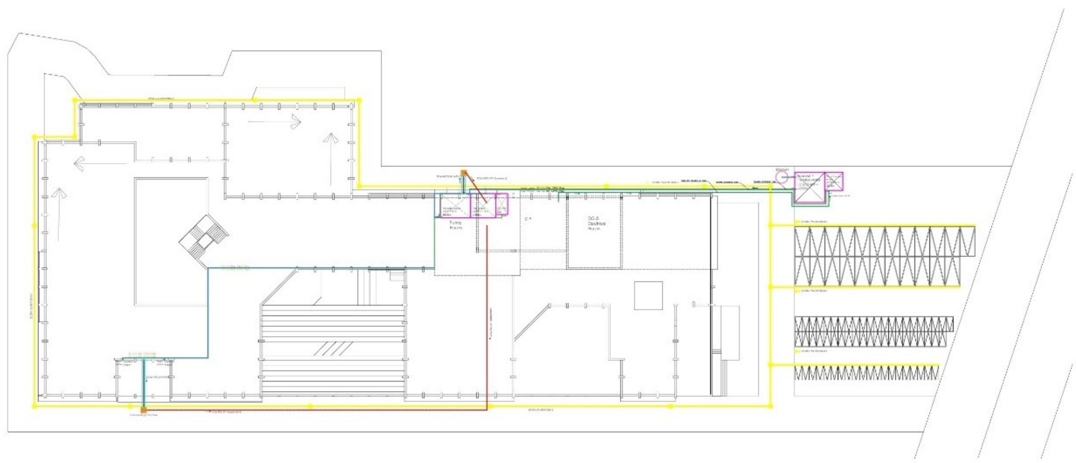


Figure 69: Electrical SLD

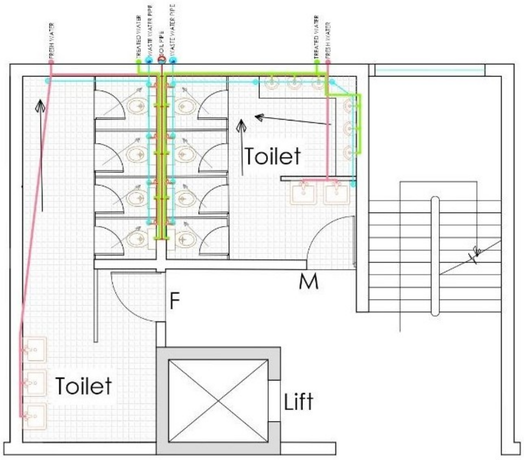
Plumbing Diagram

Figure 70: Plumbing Layout



Toilet Layouts

Figure 71: Toilet Layout



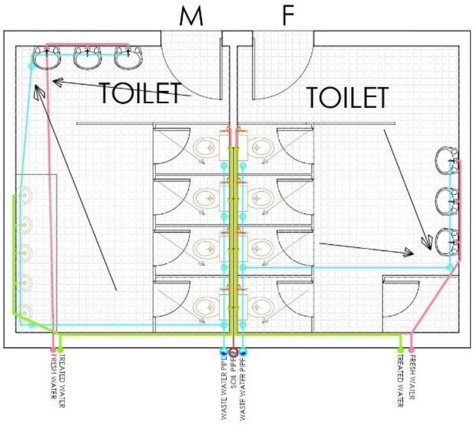
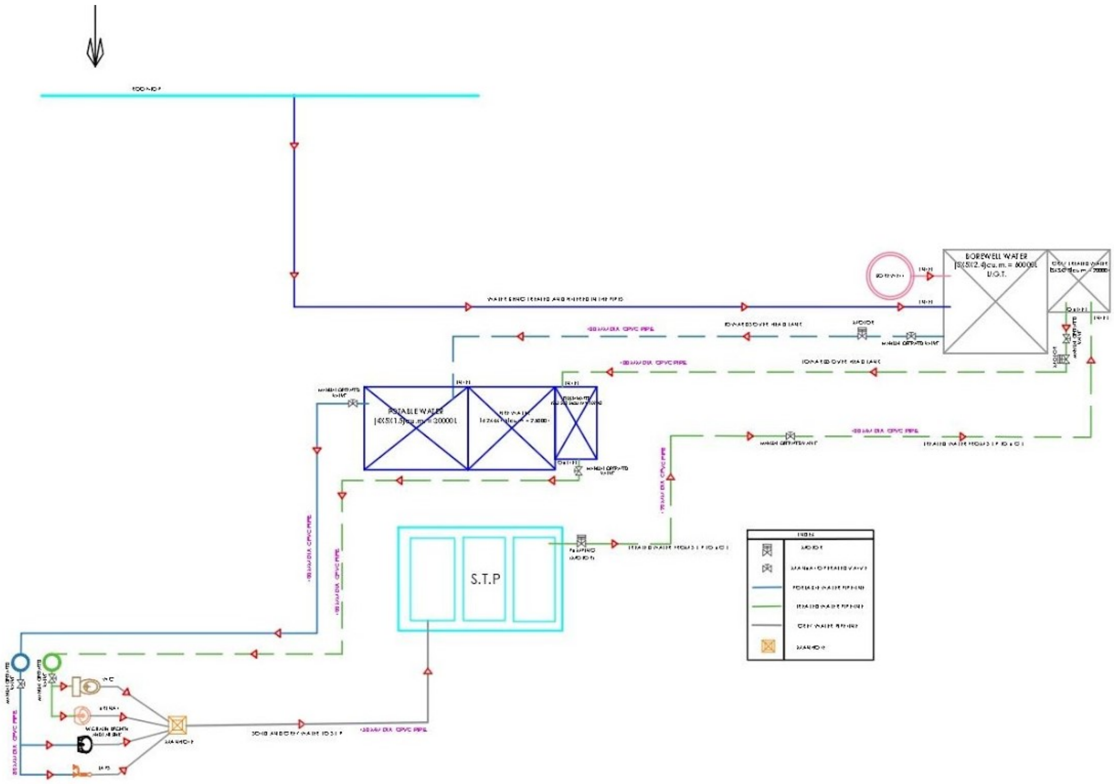


Figure 72Toilet Layout

Single Line Diagram - Plumbing

Figure 73: Plumbing SLD



Construction Details

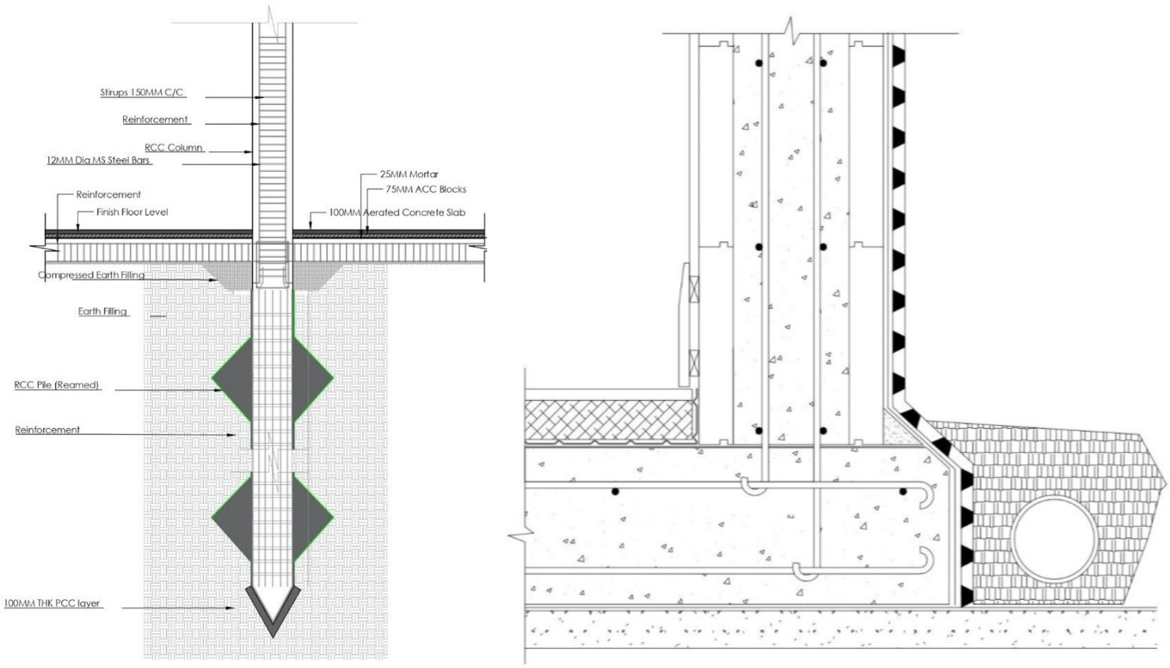


Figure 74: Plinth Details

Figure 75: Inspection Chamber Details

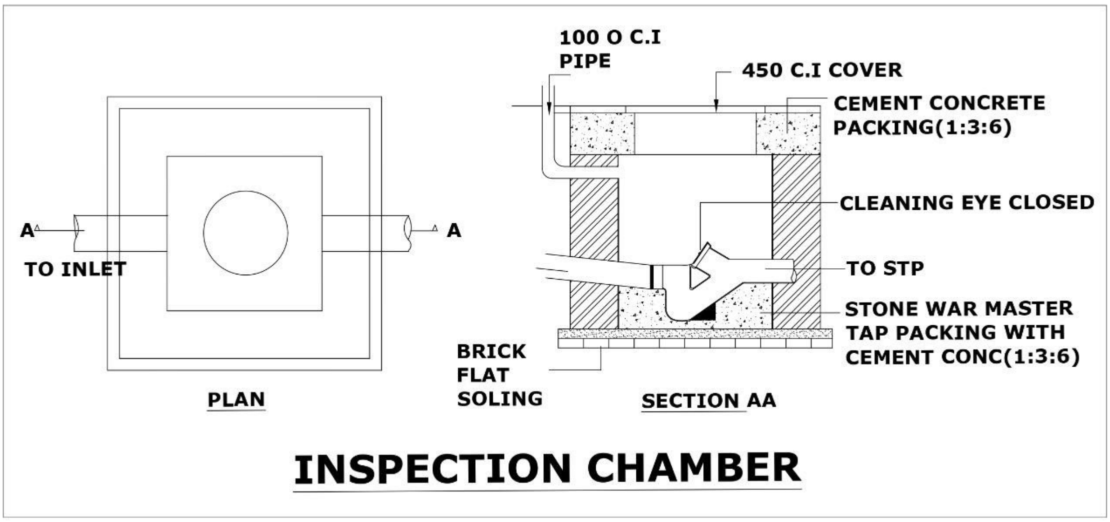


Figure 76: Type of waste generated

Waste Management System

Types of Waste Generated	
Wet Waste	Cooked food, dry leaves, compostable material
Sanitary Waste	Sanitary napkins, tissue paper, paper bag, bandages
Dry Waste	All types of paper, paper plates, office bills, cardboard, wood, plastic bags, coco bottles, water bottles, packets, E-Waste, used syringes, injections and containers, medicines, battery cells, bulbs, chemicals, Tin can, metal items, tetra pack
Garden Waste	Plant leaves, cut branches of trees.
Inert Waste	All types of construction materials.

Type of Waste	Technology Available for Processing	Benefits
PAPER	Paper recycling	End-use appliances for paper recycling generates writing a quality paper. Runs successfully as a social model. Efficiency is improving at a higher rate.
ORGANIC AND GARDEN	Composting	It is practically free destructs pathogens and kills weed seeds reduces mass and volume and odor reduces handling and transportation. acts as a soil conditioner and improves nutrient qualities. decreases pollution from chemical fertilizers. Efficiency is high
PLASTIC	Plastic recycling	Energy and natural resources are conserved Plastic recycling conserves landfill space Creates green jobs Efficiency is high.
E-WASTE	Recycling	Conserves natural resources Protects the environment Create Jobs Saves landfill space Efficiency is high
METALS	Recycling	Energy and natural resources are conserved Metal recycling conserves landfill space Create green jobs Efficiency is high
GLASS	Recycling	Energy and natural resources are conserved Metal recycling conserves landfill space Create green jobs Efficiency is high

Figure 77: Location of dustbins

Sr. No.	AREA	Number of waste Bins			
		Wet Waste	Dry Waste	Hazardous Waste	E-Waste Bin
1	External Area/Open Space	1	1	0	0
2	Toilet	0	0	1	0
3	Parking	0	1	0	0
4	Canteen Area	1	1	0	0
5	Entrance	0	1	0	0
6	Classroom	1	1	0	0
7	Corridor	1	1	0	0
8	Activity Room/Auditorium	0	1	0	0
9	Labs	0	1	1	1
10	Admin Area	0	1	0	1
11	Conference Room	1	1	0	0
12	Office	0	1	0	0

Figure 78: Paper recycling process

PAPER RECYCLYING PROCESS
Paper and cardboard from various sources
↓
Shredding and soakking overnight
↓
Bleanding paper nd water in proportion of 2:1
↓
Pouring the pulp evenly on a screen
↓
Squeezing ot the water and turning onto cardboard
↓
Allowing it to dry for 24hr.

Pitch to Project Partner

The proposed project is purely based on practicability, affordability and at the same time providing decent architectural form, spatial configuration. The building would be demonstrative example of net zero energy and water building promising the sustainability in tangible as well as intangible aspects. The project provides the opportunity to embrace the tribal community as per the project partner requirement.

Affordability

Practicability and affordability aspect is taken care by wise selection of structural system and construction techniques which is conventional in nature and provides opportunity to include local labor in construction process. The simple and down to earth form is in line with the structural system and having aesthetical appeal. This not only reduces the cost but also provide employment generation in local labor in all three phases of building construction. The material selection is done on comparative basis considering the distance from the site and hence reducing the cost of transport.

Net zero energy and water
The whole building design evolution is can be seen to achieve net zero energy and water building. This provides strong sustainability aspect to the building. The institute being architectural and design institute, the Net zero energy and water aspect would create it as a live example for all students and architectural fraternity. As IDEAS believes in sustainability in all aspects of life and students' education, the building promises to demonstrate the believes of the institute.
Innovation
Kinetic facade is one important and unique feature of the design which can provide and identity to the building at national level. This would be the first building in India to bring kinetic facades and demonstrate its application in the country creating its unique identity. The design of kinetic façade is well thought along with the estimate of its construction. This can create scalability and market potential for manufacturers in India.

The project partner can rely on the above points to consider it to be a real-life project as all the contest areas of the competition are well detailed and validated to prove it to be Net zero and water building with the help of calculations, simulations and appropriate techniques.

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Appendix B
Letter of Conformation from Industry Partner

SURMOUNT™
SAFE, SUSTAINABLE & SMART

Date: 18.02.2021

TO WHOMSOEVER IT MAY CONCERN

Surmount Energy is a pioneer in the Green Building solutions and services. Surmount offers Green Building Facilitation Services, Building Automation Solutions and Building Integrated Photovoltaic for energy generation. It serves some of the largest developers and Government bodies in India and various architects and engineers in the U.S with its offering. Surmount is a member of USGBC, IGBC, ASHRAE, ISHRAE, BEE, ISLE and core committee of 'IGBC Green Industrial Buildings'.

We hereby declare that Surmount Energy Solutions Pvt. Ltd. is the Industry Partner of Team Ferb from Institute of Design Education and Architectural Studies (IDEAS), Nagpur working on Educational Building Typology.

Regards,

Ar. JP Rout
(Head – Sustainable Solutions)

B-003-004, Platform Level, 1st Floor, Tower #10, ITC, Belapur Station Complex,
CBD Belapur, Navi-Mumbai 400614, India.

DC ENGINEERING

Date: 14.04.2021

DC Engineering is HVAC Solution Provider Company having HO in Nagpur and branch office Sangli. We are the Authorized channel partner for "MITSUBISHI ELECTRIC & HITACHI" for Centralized Air Conditioners. We stand for quality, consistency and technical support in the field of HVAC systems. Warded with quantum of new works and repeated orders from most of our clients we have a competent team of experienced engineers, technical supervisors, draughtsman and skilled work force having expertise ranging from 5 to 10 years and are capable of accomplishing any kind of magnitude of work.

TO WHOMSOEVER IT MAY CONCERN

We hereby declare that DC Engineering, Nagpur is the Industry Partner of Team Ferb from Institute of Design Education and Architectural Studies (IDEAS), Nagpur working on Educational Building Typology.

With Best Regards,

Piyush Sahu,
Director.
DC Engineering, Nagpur.

Office : 1137, Near Saini Travels, Central Avenue, Gandhibagh, Nagpur - 440002 (M.H.)
Cell No.: 7620574988, E-Mail ID : dcengineering14@gmail.com

Letter of Confirmation of Project Partner

सह वीर्यम् करवाव है

Swargiya Jagannath Jattewar Shikshan Sanstha, Nagpur.

ideas institute of design education & architectural studies, Nagpur

IDEAS/SDI/2020-21/ 251

Date: 14.09.2020

To,
The Director,
Solar Decathlon India

Dear Sir,

This is to inform you that our organisation, IDEAS-Institute of Design Education & Architectural Studies, Nagpur, has provided information about our Educational Building project to the participating team led by IDEAS-Institute of Design Education & Architectural Studies, Nagpur, so that their team TEAM_FERB may use this information for their Solar Decathlon India 2020-21 competition entry.

As a Project Partner to this team for the Solar Decathlon India 2020-21 competition, we are interested in seeing the Net-Zero-Energy, Net-Zero-Water, resilient and affordable solution this student team proposes and the innovation that results from this. We intend to have a representative from our organisation attend the Design Challenge Finals event in April, if this team is selected for the finals.

We would like our organisation's logo to be displayed on the Solar Decathlon India website, recognising us as one of the Project Partners for the 2020-21 competition.

With warm regards,

Prof. Abhay V. Purohit
Principal
IDEAS, Nagpur
Email: principal@ideasnagpur.edu.in
Mob.: 9922556866

Principal
ideas
Institute of Design Education & Architectural Studies, Nagpur

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Central Office - 469, Tiranga Chowk, Sakkardara, Nagpur-09 Tel. : 0712-2744577 Email- ideasnag@gmail.com Website - www.ideasnagpur.org