Team "Mrittika"

Office Building
Final Design Report – April 2022

School of Planning and Architecture, Vijayawada

Jadavpur University, Kolkata

Puducherry Technical University, Puducherry

Sarda Group Corporate Office, Raipur

Solar Decathlon India

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1. Executive Summary-

'Team Mrittika' is composed of eight students from different institutes and backgrounds who came together to design a net zero corporate headquarter for the Sarda Group located in the Amaseoni area of ***Raipur, Chhattisgarh***. This project was taken as a challenge to understand the constraints and apply an ***integrated design*** approach into a commercial greenfield project to develop their knowledge by communicating with industry experts and to design a ***iconic workplace*** that will be projected for ***net zero sustainability***.

The design constraints put forward by the client stated that ten different departments should be consolidated into the plan along with the services, common amenities & a multi-purpose hall in an ***integrated manner*** and that the building should be largely conditioned to maintain indoor occupant comfort and also a corporate workplace environment. So the major challenge was to go ***beyond the stereotypes*** and provide spaces which ***encourage creativity*** and ensure ***vibrant, healthy and cohesive working environment*** while optimizing the parameters to achieve the goal of ***net zero energy, water*** and many more.

With a ***6640 sqm of built up area***, the preliminary goals of this project were set to design an office building with an ***EPI lower than 90 kW/hr/year***, maximizing renewable energy potential from the large external envelope to ***offset*** the annual consumption, ***reduce*** the total fresh water demand while harnessing the ***water conservation*** during the monsoon period, illustrate the ***use of local*** materials, craftsmanship and induce ***cultural identity***, incorporate ***resilient design*** decision to strengthen the adaptability to unforeseen disasters and climate change, optimize the ***building management system***s and integrate landscape to ***induce biophilia*** while enhancing ***indoor environmental quality, outdoor microclimate*** control to ensure thermal comfort, occupant ***health and wellbeing*** while fostering environmental sustainability.

The energy generation potential from the renewable energy sources was found to be ***5,81,714 KWh*** and therefore target EPI for the project was set at ***87.6 kW/hr/year***. The EPI was reduced to ***56.2 kW/hr/year*** by integration of active and passive design strategies such as climate responsive ***spatial zoning***, optimization of ***envelope assembly***, mixed mode ventilation, efficient ***day lighting***, façade and rooftop ***shading***, energy efficient ***lighting*** fixtures and zone wise ***HVAC systems***.

The baseline fresh water demand of 45 KLD was reduced to ***27.1 KLD*** by integrating water ***efficient fixtures***, ***drip irrigation*** technique with ***recycling and reusing*** of grey water. Furthermore rain water harvesting system was adopted at the building and site level to offset the fresh water consumption to achieve net zero water by harnessing the huge potential of stormwater runoff during the monsoon months of almost 1400 mm.

The challenge in Innovation was facilitated in two ways- ***design innovation*** through amalgamation of the wellness office concept by providing central spaces for social interaction while maintaining social distancing and technological innovation by incorporating BAPV panels on the west façade and ***waste to energy*** generation systems in the building. Flexibility in planning was achieved by using a ***flat slab*** technique which reduced the number of columns required while maintaining structural stability. Green pockets were provided on every floor to maintain the ***IEQ*** and ***vibrant, native vegetation*** palette was selected for improving the overall ***microclimate*** of the site.

2. Team Introduction

2.1 Team Summary

a. Team Name – Mrittika

b. Institutions Name –

i. School of Planning and Architecture, Vijayawada
ii. Jadavpur University, Kolkata
iii. Puducherry Technological University

c. Division – Office Building

d. Team Members – Team ***"Mrittika"*** comprises of 8 members that includes 5 PG students from sustainable Architecture (M.Arch) and one UG (B.Arch.) student from ***School of Planning and Architecture, Vijayawada*** and is further strengthened by two civil engineering student (UG & PhD) from ***Jadavpur University*** and ***Puducherry Technical University*** respectively for a holistic outcome.

Subham Das
PG student (MSA)
Team Leader / Architectural Design & landscape, ecology

Sayak Banerjee
PG student (MSA)
Resilience & health & wellbeing

Priyanka Jaiswal
PG student (MSA)
Architectural Design, Scalability & market potential

Harshita Sahu
PG student (MSA)
Energy Performance & Innovation

Jatin Kashyap
PG student (MSA)
Water Performance

Haritha Telukula
UG Student (B.Arch.)
Communication

Deeptarka Roy
UG Student (Civil)
Affordability

Seeralathan B
Civil Engineer (PhD)
Engineering and Operation

e. Background of the Lead Institution –

School of Planning and Architecture, Vijayawada is one of the three institutes of national importance, under the Ministry of Education (MoE), Government of India, established in 2008 by MHRD. The institute academic degree programmes are designed to address physical, socio-economic and environmental challenges, so as to achieve future sustenance and hence to cater to the specific needs of the industry and academics in the fields of Planning and Architecture by undergraduate, post graduate and doctoral programs in the aforementioned fields. The institute holds the 8th Position in NIRF Ranking nationwide for Architecture.

f. Faculty Lead and Faculty Advisor –

Dr. Iyer Vijayalaxmi Kasinath
B.Arch., M.Arch., PhD., Higher Research, Post-Doc
Faculty Lead

Dr. Faiz Ahmed Chundeli
B.Arch., M.Plan., MURP (France), PhD.
Faculty Advisor

Dr. Iyer Vijayalaxmi Kasinath is a Professor in the Department of architecture at SPA Vijayawada with more than 25 years of teaching experience.
Dr. Faiz Ahmed Chundeli is an Assistant Professor in the DoA at SPAV. He is a researcher and built-environment analyst.

g. Industry Partner-

Vighneshwar Air conditioning Pvt. Ltd, a leading HVAC engineering company spanning all over India, specialized in providing qualitative HVAC solution for high rise buildings, banks, large office premises, IT call centers, pharmaceutical industries, Hospitals, Multiplexes, Shopping Malls etc. Team Mrittika worked with Mr. Vivek Sutar to optimize the target EPI and also to develop the HVAC design.

Innards Infrastructure Private Limited, specialist in high-performing healthy environments, building integrated agriculture, Hydroponics system and provide solutions on the wellness living experience with design, innovation, sustainable product and services. Team Mrittika worked with Mr. Shiladitya Roy on indoor vegetation systems, innovation and alternatives for enhanced IEQ and wellbeing.

2.2. Design Management Process

Considering the ***10 contests of SDI***, an ***integrated design approach*** was adopted. Team members from diverse fields conducted regular meetings with the project partner, faculty lead, industry partners & advisors to create a ***comprehensive framework*** to address the spatial requirements along with the ***net zero design solution*** envisioned with the future provision.
Initially each of the ***10 contests*** were studied for an in depth understanding of the requirements, synergy and the design strategies pertaining to holistic integration that could be incorporated into the ***integrated design development***. This was strengthened by ***literature and case studies*** related to climate responsive design, offices and net zero building to summarize the inferences which was further optimized by a holistic ***context analysis*** from the macro to micro level, followed by the ***site analysis*** highlighting the indicators of climate, socio-cultural, environmental and market economy.
Architectural design matrixes has been drawn with all these inferences for the integrated set of passive and active design strategies for achieving climate responsive energy efficient built environment. Architectural design ***emphasized as a tool*** for efficient spatial planning to reduce the built up area which eventually reduces the embodied energy as well as the operational energy

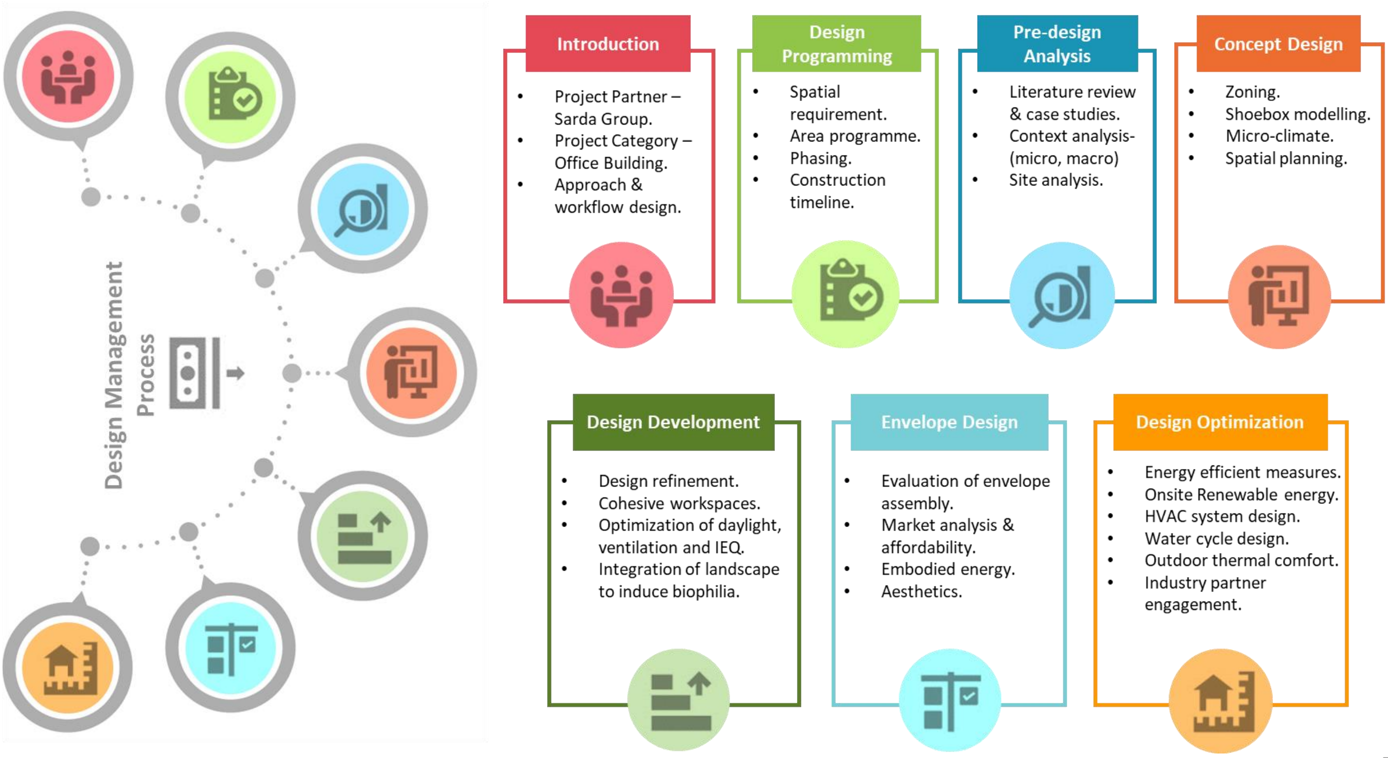


Fig. 1 : Design Management Process

[All the vectors are sourced from Google images]

followed by the efficient structural & services design further ***reducing energy demand*** .
The ***design development*** focused on the refinement of the internal planning and envelope design to achieve the indicators of daylight, natural ventilation, IEQ with the ***optimization of envelope assembly*** with appropriate consideration from market analysis, affordability, embodied energy while fostering ***cultural identity, aesthetic harmony*** in a vibrant, cohesive workplace.
Further, appropriate ***water cycle design*** was also proposed both at the building and site level to minimize the fresh water demand aiming towards ***net zero water*** along with ***optimized BAPV system*** designed at the building level to maximize onsite energy potential towards a ***net zero energy design*** reducing the energy demand with an effort towards ***environmental sustainability.***
Finally site level ***waste management*** was proposed for a ***zero waste site*** to set an exemplary ***Net zero office building*** in the socio-economic context of an emerging business district of Raipur.

Fig. 2 : Team Formation

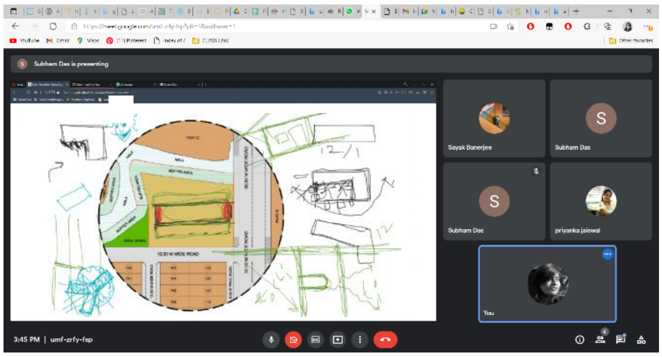


Fig. 3 : Internal online discussion for building footprint

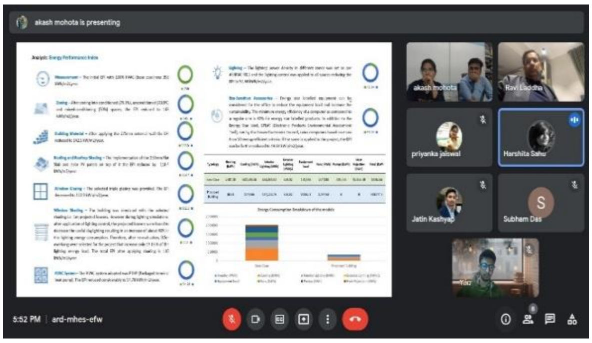


Fig. 4 : Design discussion with client "Mr. Ravi Laddha" and his architect "Ar. Akash Mohota"

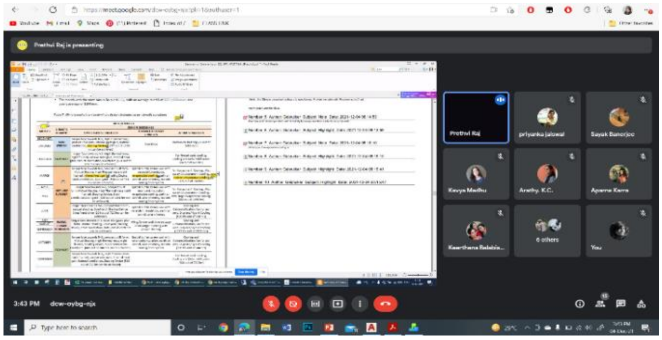


Fig. 5 : Design discussion with external industry expert "Ar. Prethvi Raj"

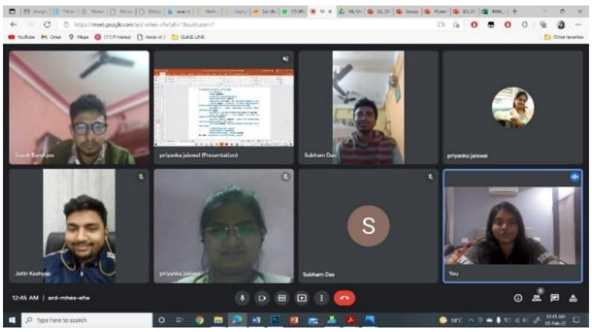


Fig. 6 : Internal discussion

Fig. 7 : Tools used for the design project

[All the logos are sourced from Google images]

Tools used –

Figure 7 represents the tools used for design and optimization of the office project. ***AutoCAD*** and ***SketchUp with V-Ray*** were used for 2D and 3D design. Other software's like Climate consultant, Design Builder, Formit, DIALux, Rhino with Grasshopper (Ladybug, Honeybee, DIVA) etc. were used for ***energy, climate, daylighting and CFD simulations***. While MS Office, Photoshop were used for graphic ***illustration, report making, estimation*** etc.

3. Project Introduction

a. Project name – Sarda Group Corporate Office

b. Project partner – Sarda Group

It is a prominent business organization, headquartered in Raipur, Chhattisgarh, India. Over the last four decades, the group has established 15 different companies across multiple domains & sectors including energy (hydropower and solar) and natural resources etc. Their commitment to reinvent the real estate sector prepared them to look beyond the obvious and shape many pioneering commercial as well as premium affordable housing projects.

Key Individuals –

Mr. Ravi T. Laddha	**Mr. Saroj Kanti Som**
Executive Director (Mines and Projects)	Deputy General Manager (Projects)

c. Brief Description of Project –

The office building is a part of the ***Shriram Business Park (SBP)*** project by the Sarda Group. SBP is a mixed-use development with 60% and 40% land reserved for commercial and residential usage respectively. The project is located in the Amaseoni area of ***Raipur*** (Co-ordinates : 21.25°N, 81.63°E), Chhattisgarh and falls under ***composite climate*** as per ECBC.
The office project is currently at the ***planning stage***. The corporate office is being built for the ***employees of Sarda group*** with a provision for 250 employees occupying for an 8-hour office shift from ***9:00 am to 5:00 pm*** during 6 days a week. Number of visitors expected are between 5-20 per day. Also, the future expansion for 30 people is also considered consecutively.

d. Special requirements of the Project Partner –

- Multi-purpose hall having capacity of 250 people is a must & a Conference hall with the capacity to seat 30 people with audio-visual facility to be provided on each floor with conditioning in most of the spaces.
- The project should fulfill the local guidelines as well as NBC norms for Fire fighting.
- The project must incorporate Sewage Treatment Plant and Rain Water Harvesting.
- Total project cost as estimated is 48.74 Crores @ 52,536 Rs. per square meter.

e. Site details and total built-up area –

The Proposed Site comes under ***Part F*** commercial zone as Commercial Block "123" in the SBP site plan with the Net Plot Area of ***4808.83 Sq.m*** divided into the buildable plot area of ***3797.30 sq.m***. and mandatory Buffer Area of ***1011.53 sq.m.*** The corner plot will be accessed from ***30.00 m*** arterial road towards the **East** and **12.00 m** wide internal road towards the **South**.

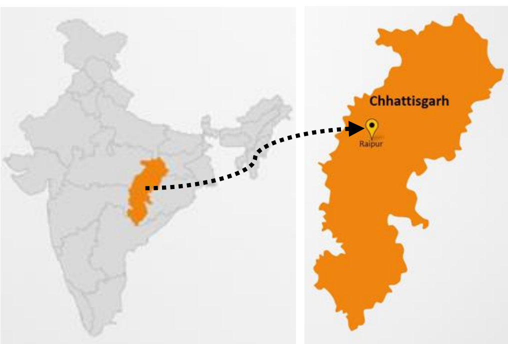


Fig. 8: Map of India, Chhattisgarh
[Source : Google images]

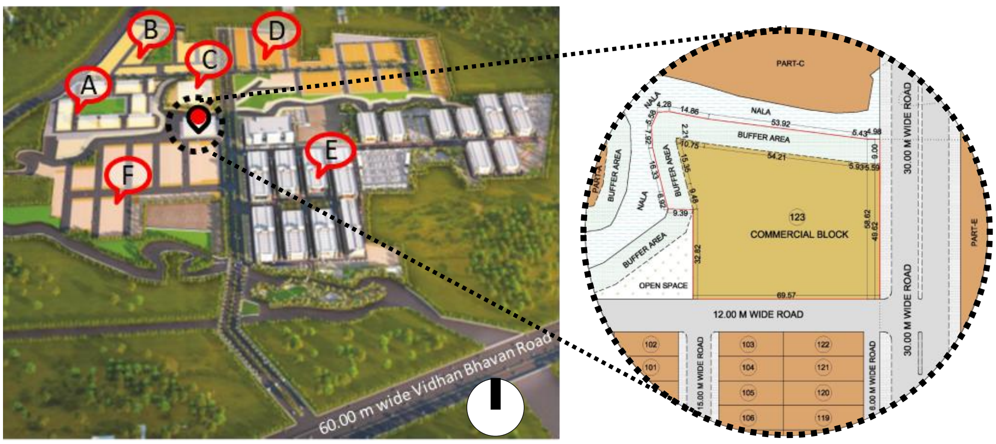


Fig. 9 : SBP layout and Proposed Office site – Commercial Block No. 123

There is a seasonal storm water channel present towards N,N-W side through which surface drainage is to be carried out. The site is an open land with **flat topography** (leveled surface as per the entire layout). It has nominal ground cover and there is no such major plantation on site. Also, there is no obstruction in 100 m radius of the site.

Table 1 : Permissible FAR and ground coverage

Permissible	Area as per site
FAR - 3	4808.83 x 3 = 14426.49 Sq.m.
Ground coverage - 30%.	3797.30 x 0.30 = 1139.19 Sq.m.

The total built-up area calculated as per the detailed area programming provided in Annexure- Sr no. 1,2 is ***6639.10 Sq.m***, with the remaining permissible area to be reserved for ***future expansion as per the client's requirement .***

f. Preliminary construction budget (INR/m²) and timeline –

The preliminary unit cost is 35,000 INR/m². Approximate construction area is 9300 sq.m. with the project budget being 32,55,00,000 INR and the expected timeline for the project completion is 2 years. The timeline of 16 months is illustrated in figure 10 given below, and the remaining 8 months are reserved for interior and furniture works.

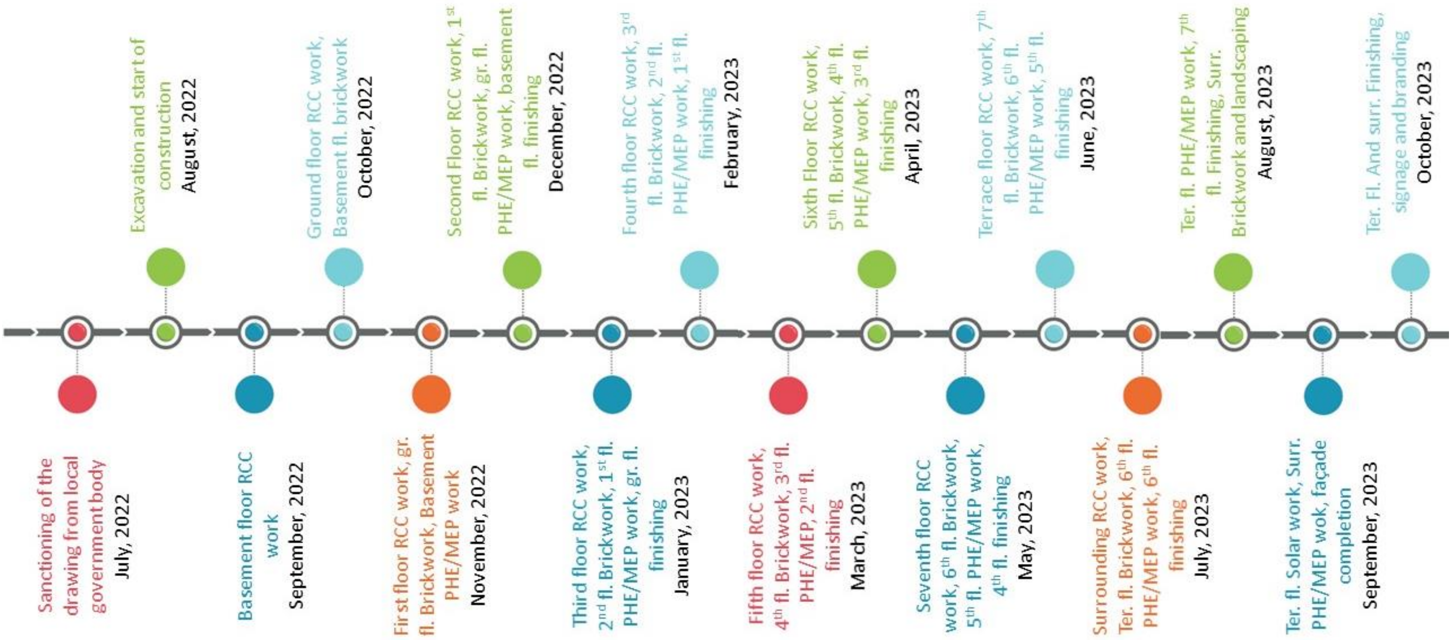


Fig 10 : Construction timeline

4. Goals & strategies

Energy Performance

Aim:

To reduce the EPI up to 92 kWh/sq.m. year

Strategy:

Integration of passive (orientation, envelope optimization, shading, natural ventilation, daylight) and active design strategies (LPD, HVAC, equipment load optimization). Offset the energy demand using BAPV (roof, façade), biomethanation and waste to energy plant to harness potential energy generation from organic and inorganic waste.

Water Performance

Aim:

To reduce the overall water demand by 65% considering future expansion.

Strategy:

Water efficient fixture, sensor based equipments, drip irrigation system to reduce the freshwater demand by 37.5% (27.1 LPCD) and it is further optimized by reusing grey and sewage water for flushing and irrigation, whilst maximizing rain water recharge potential from roof and site drainage.

Resilience

Aim:

To make the building resilient to withstand changing environmental condition, natural calamities (earthquake, flood, heat waves) and economical challenges.

Strategy:

Reduce the operational energy and water demand for the building to sustain for longer periods in case of unforeseen precedents. Flexible planning with large span spaces to adapt to changes in building use.

Architectural Design

Aim:

To go beyond the stereotypes and provide spaces which encourage creativity and ensure vibrant, healthy and cohesive working environment while achieving the other goals through for a integrated solution.

Strategy:

Integration of passive strategies validated with efficient spatial planning w.r.t climate and functional requirements. Exploiting the daylight potential to achieve a minimum of 90% of area throughout the year. Narrow floor plan with optimized fenestration technique to increase the daylight and natural ventilation (6-10 acph) potential in the open plan workspaces while ensuring connection between the intense work environment and nature inducing biophilic strategies.

Health & wellbeing

Aim:

Ensuring indoor environmental quality (air quality, visual, thermal & acoustical comfort)

Strategy:

Maintaining ASE below 3% and illumination of 300 lux for 90% area through efficient fenestration technique. Garden spaces alongside AHU for improving indoor air quality. Climate responsive envelope design to ensure indoor thermal comfort for 40% of the office area comprising open plan system with natural ventilation. No VOC materials with air purifying plants for better air quality.

Landscape & ecology

Aim:

To enhance biodiversity and build a resilience against environmental threat.

Strategy:

harnessing potential of landscape cover to maximize carbon sequestration, reduction in UHI effect, soil erosion along with increase in biodiversity, riparian ecosystem while ensuring outdoor thermal comfort, air purification, ground water recharge, health and wellbeing by inducing biophilia and emphasis on diverse plant pallet focusing on native drought tolerant plant, agroforestry etc.

Engineering & operation

Aim:

Minimize material waste, energy consumption during construction & operation.

Strategy:

Use of flat slab system for better management of building services. Building management system (BMS) to monitor and optimize energy use during operational phase. VAV Water Cooled Chiller (absorption) will be installed for HVAC system which uses 35 kWh/sqm. 64% less than conventional cooling system.

Innovation

Aim:

To Innovate in on site renewable energy sector to offset the energy demand

Strategy:

Use of BAPV in the west façade and waste to energy plant (as Refuse-derived fuel) along with biomethanation tank that generate renewable energy from inorganic and organic waste (36 % of the total energy demand) which will allow the office campus to become a net zero waste as a benchmark project.

Scalability & Market potential

Aim:

To set a exemplary Net zero office building in the socio-economic context of a emerging business district of Raipur.

Strategy:

Structural consideration of Flat slab for spatial flexibility and modularity along with climate responsive integrated design framework with optimized metrics, for a replicable model for a net zero office in similar climate and promotion of technological innovation, local material, indigenous art, craftsmanship will also help to create dynamics of target population.

Communication

Aim:

To strengthen the potential of net zero office building among the client, user and visitors

Strategy:

Built environment performance with energy audit publication and effective payback period publishing in the leading journals, media and by conducting seminars to outreach the impacts of net zero office building for sustainable future.

Affordability

Aim:

Maximize affordability through payback assessment and cost-impact analysis from client perspective.

Strategy:

Emphasis on passive design strategies, local cost effective material, construction management with smart building systems to reduce the operational cost.

5. Performance specification

Table 2: Performance specification for envelope systems (refer Annexure sr no. 8)

Climate	**Composite Climate (as per ECBC)**	
Category	**Material/ equipment**	**Technical specification**
Envelope Systems		
Wall	***275 mm*** insulated AAC Block wall	The wall has 12.5mm cement plaster on each side, 2 layers of 100mm AAC blocks with one 50mm layer of rice husk insulation in the middle. ***U-value*** = 0.323 W/m²K
Roof	***230 mm*** Insulated RCC Slab on the top floor	19mm Asphalt on top along with 13mm Fiberboard and 48mm XPS insulation above a 150mm Concrete Slab. ***U-value*** = 0.457 W/m²K .
Floor	***212.5 mm*** RCC Slab in the middle floors	150mm RCC slab with layers of 12.5mm plaster below and 40mm sand and 10mm tile above for the middle floors. **U-value** = 1.96W/m²K
Fenestration	***Triple Glazing*** LoE 3mm/13mm Ar glazing	3 layers of 3mm LoE glass with 13mm argon gas filling. ***U-Value*** = 1.058 W/m2K ***SHGC*** = 0.579 **VLT** = 0.698 (69.8% of visible light transmitted) 0.5m Overhang were selected for shading on the north façade with screens on the west façade, BAPV on the east façade and staggering on the south façade

Table 3: Technical specification for Active and Renewable energy systems

Category	Material/ equipment	Technical specification
HVAC System		
ALL Floors	VAV Water Cooled Chiller	35 kW/m² Auxiliary power.
Electrical Load – ASHRAE 90.1 compliant		
Lighting Space specific	Sensor based LED lights with lighting controls	Lighting Power Density (LPD) – 5.4 – 11.5 W/m²
Equipment	Workspace equipment like computers, printers, etc.	Power Density – 12.5 W/m²
Plumbing system		
Wash Basin/ faucet	Water efficient sensor based faucet	Battery operated sensor faucet with controlled Flow Rate due to efficient flow restrictors- 0.5 Bar-5.10; 1.0 Bar-7.20; 2.0 Bar-10.50; 3.0 Bar- 12.78 Water savings 60 % up to 80% (1.8 L in 12 seconds)
Urinals	Waterless urinals	Functioned only by a mechanical valve system and doesn't require a cartridge change every other month.
Water closet	Dual flush systems	Dual flush 4/2L WC cistern with bottom inlet for compact back to wall Rimless toilet Cistern Dimensions: L x W x H: (365X150X405)mm Water closet Dimensions: L x W x H: (365X600X790)mm
Renewable energy System		
Rooftop Solar Panels	Mono PERC Module, 72 cell	Dimension: 1660x1000x46 mm ***Output: 390 W*** Module efficiency: ***19.45 %***
Building-integrated Photovoltaic (BAPV)	Multi crystalline (PERC), 72 twin cell	Dimension: 2108x1048x40 mm ***Output: 335 W*** Module efficiency: *17.18 %*
Bio methanation	Organic waste treatment	Total production capacity: 15 kw (projecting future provision) Total plant capacity: ***24 CUM***
Waste to energy plant	Inorganic waste treatment	Total production capacity: 25 kw (projecting future provision) Total plant capacity: ***36 CUM***

Water supply and distribution systems –

Separate **Hydro-pneumatic System** is designed for domestic and flushing systems which pumps water from underground water tanks to the respective utility points of the office at respective floors.

Sewage Treatment Plant–

The scheme proposed for the treatment of sewage is a compact and effective Sewage Treatment Plant using the revolutionary "**Moving Bed Bio Reactor (MBBR)**" technology.

6. Design documentation

a. Site Analysis

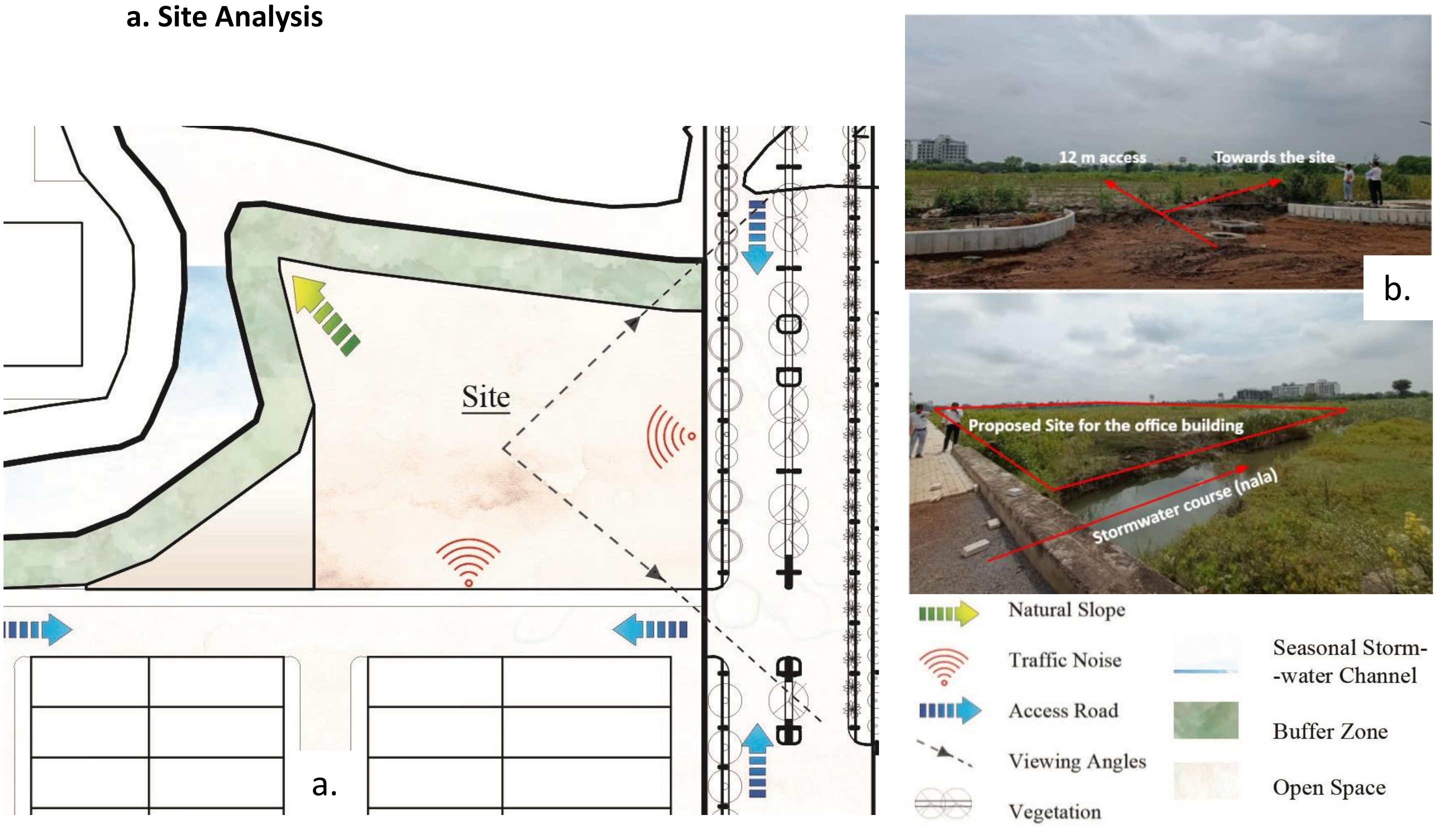


Fig. 11: a) site layout b) existing site images.

The proposed site abuts a 30m main road on the east and a 12m access road (yet to be constructed) in the south. The west side is currently vacant. There is a storm watercourse abutting the north side of the plot. A 9m buffer, is to be provided along the watercourse (nala).

The storm watercourse is ***seasonal*** and is filled only during monsoon. The site does not have ***any full grown trees***. The visible tree line is 206m away from the site and outside the development area.
Street lights and pavements along the 30m main road has been constructed. Utilities such as IC for sewerage pipes and electrical wires have been provided on the pavements as well as along the roads. A separate stormwater drain has been provided that connects to the Nalas. Alongside the site Kadam trees (native), Opposite the site palm trees (exotic) and in the center Gulmohar trees have been planted by the developer as no full grown trees were available on the site.
The recommended ***viewing angles*** are the east (overlooking the central boulevard), south and west (overlooking the other building blocks) directions. The north view should be ***restricted to a certain extent*** due to the presence of the Nala. Certain buffer should be provided to obstruct the view.
As the east boundary of the site abuts the central 30 m road and the surrounding area is being developed as a commercial block, the ***traffic*** is expected to be heavy and consistent on all days.
Post monsoon water table is around 3-5 m BGL at proposed site. Extra precautions to be taken during building construction and basement provision. The pH value ranges from 7.65 to 8.3 and is within the prescribed limit by BIS.
The AQI of the region is considered ***poor***. Therefore trees that act like carbon sinks and reduce the harmful air contaminants are considered for landscaping in ***outdoor and indoor*** areas.

b. Climatic Analysis

The climate analysis has been exercised extensively and the synthesis are been rationalized by distributing it into ***4 primary climatic segments*** to strategized the inferences into a ***preliminary framework*** that is composed with ***simple, advance passive strategies*** along with ***active strategies*** more comprehensively with the conclusive references from literature reviews and case studies.

Table 4: Climatic Segment analysis (refer Annexure sr no. 4)

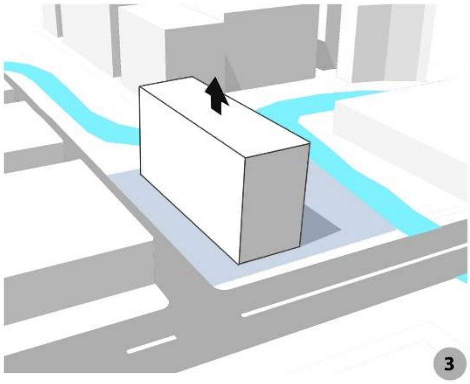
	Segment 1	**Segment 2**	**Segment 3**	**Segment 4**	**Segment 2**
	Dec - Jan	**Feb**	**March - June**	**July - Sep**	**Oct - Nov**
Aspects	**Mild winter** **Moderate discomfort**	**Moderate** **Comfort**	**Hot and dry summer** **Higher discomfort**	**Warm, humid monsoon** **Higher discomfort**	**Moderate** **Comfort**
DBT (°C)	**Mean :** 20(D), 19(J) **Avg high:** 26 **Avg. low:** 14(D), 12(J)	**Mean :** 23 **Avg high:** 30 **Avg. low:** 17	**Mean:** 17(M), 32(A), 34(M), 30(J) **Avg high:** 34(M), 38(A), 40(M), 35(J) **Avg. low:** 20(M), 24(A), 26(M,J)	**Mean :** 26-27 **Avg high:** 30 **Avg. low:** 25	**Mean :** 25(O), 23(N) **Avg high:** 30(O), 26(N) **Avg. low:** 20(O), 18(N)
RH (%)	**Mean :** 68(D), 51(J) **Avg high:** 75(D), 60(J) **Avg. low:** 55(D), 40(J)	**Mean :** 55 **Avg high:** 60 **Avg. low:** 45	**Mean:** 46(M), 40(A), 37(M), 63(J) **Avg high:** 52(M), 45(A), 42(M), 65(J) **Avg. low:** 39(M), 36(A), 34(M), 57(J)	**Mean :** 80-85 **Avg high:** 90 **Avg. low:** 70-76	**Mean :** 65(O), 73(N) **Avg high:** 75(O), 80(N) **Avg. low:** 50(O), 63(N)
Wind Dynamics	**Direction:** N, N-E **Velocity (m/s):** mean 1.5-2 **RH (%)** : 30-50 (avg) **Temp.(°C)** : 21-27	**Direction:** N, N-E **Velocity (m/s):** mean 1.5-2 **RH (%)** : 30-50 (avg) **Temp.(°C)** : 27-30	**Direction** : N, N-E, W, S-W **Velocity (m/s):** mean 3-4 **RH (%)** : 30-35 (avg) **Temp.(°C)** : 35-38	**Direction** : S-W, W **Velocity (m/s):** mean 4-5 **RH (%)** : 75-90 (avg) **Temp.(°C)** : 27-30	**Direction** : N, N-E **Velocity (m/s):** mean 2-3.5 **RH (%)** : 40-60 (avg) **Temp.(°C)** : 25-28
Sky Cover (%)	**Mean :** 24(D), 5(J)	**Mean :** 20	**Mean :** 15(M), 33 (A), 27(M), 62(J)	**Mean :** 76(J), 75(A), 63(S)	**Mean :** 20(O), 40(N)
Radiation (GHR) (Wh/sqm.)	**Mean :** 325(D), 400(J) **Avg. High & low:** 725,95	**Mean :** 425 **Avg. High & low:** 775, 210	**Mean :** 520(M), 535(A), 575(M), 450(J) **Avg. High & low:** 1000, 150	**Mean :** 370(J), 340(A), 375(S) **Avg. High & low:** 700, 95	**Mean :** 400(O), 335(N) **Avg. High & low:** 750, 95
Sunshine hours	**Avg. daily :** 8.5(D), 9(J) **Monthly :** 280(D), 290(J)	**Avg. daily:** 10 **Monthly total:** 270	**Avg. daily :** 10(M), 11(A), 11.5(M), 10.5(J) **Monthly :** 335(M), 340(A), 365(M), 320(J)	**Avg. daily :** 7.5(J), 6(A), 8(S) **Monthly :** 230(J), 200(A), 245(S)	**Avg. daily :** 8.5(O), 9(N) **Monthly :** 270(O), 260(N)
Preliminary design strategies (concluded from literature reviews, case studies)					
Simple Passive Strategies	East-West longer axis- High Thermal mass (roof and floor)- Passive solar gain- Internal heat gain- Natural Ventilation.	East-West longer axis- -Natural Ventilation- Mutual shading, microclimate control with courtyard planning.	East-West longer axis- Compact built form with narrow footprint- Natural Ventilation- Shading Device- Mutual shading, microclimate control with courtyard planning.		East-West longer axis- High Thermal mass (roof and floor)- Optimum solar gain- Internal heat gain- Natural Ventilation.
Advanced Passive Strategies	Insulation-High Thermal mass with night flush ventilation		Spatial buffer (screen wall with verandah), Insulation, Stack Ventilation-High thermal mass with night flush ventilation evaporative cooling- radiant cooling floor system	Wing/Screen wall with vegetation- Stack Ventilation-High thermal mass with night flush ventilation	Spatial buffer(screen wall with verandah)- Insulation- High Thermal mass with night flush ventilation- Radiant cooling floor system
Active Strategies	Optional mechanical heating.	Fan forced vent. cooling	Fan forced vent. Cooling- Displacement Cooling- two-stage evaporative cooling;	Cooling and Dehumidification- Fan forced ventilation- Displacement Cooling;	
Other Strategies	• Rooms are single banked, permanent provision for air movement and daylight penetration; • Envelope optimization to minimize solar heat from west, south and east; also maximize the potential of Solar PV from the envelope • Medium openings, 20-40% (30% WWR taken for daylighting and air changes) majorly at the north and south; • Integration of landscape into the built environment, provision for outdoor thermal comfort to enhance outdoor activity; • Protection for opening from hot and cold wind, rain and glare (appropriate shading devices);				

Note: refer Annexure sr no. 5, for case study inferences

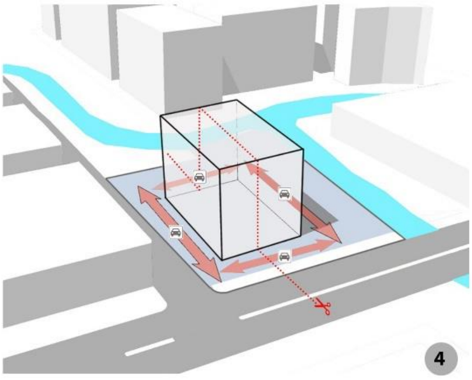
c. Form Evolution *(refer Annexure sr. no. 8)*

synergy between nature, people and built environment.

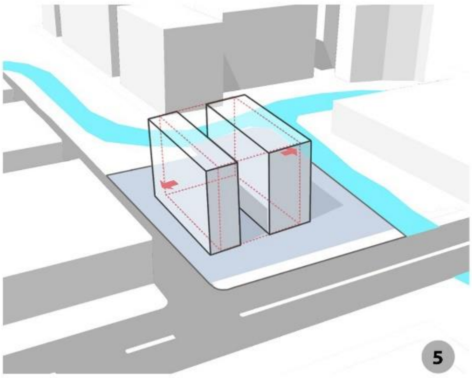
site adjascent to street corner and a stromwater swale.



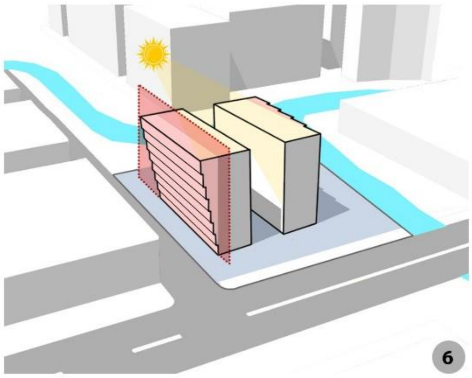
the built form is extruded upto 7 storey maintaining east-west longer axis.



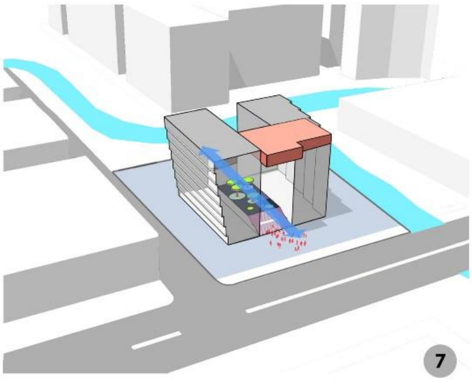
peripheral driveway converted the footprint towards a compact plan form.



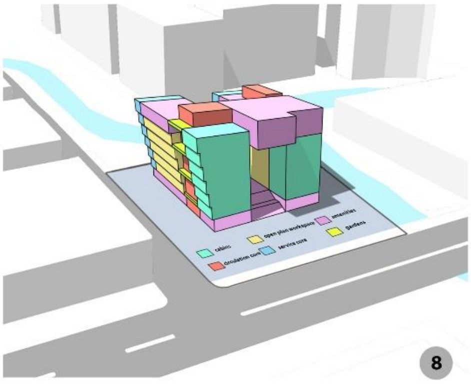
the building is divided into two linear blocks for better ventilation and daylight.



addition of floor spaces result in self shading and increased roof area for solar pv potential.



podium with multiple activity is added as an integral space at the entry level for better interaction.



the service spaces are provided towards west to restrict heat ingress, cabin spaces towards the east for best view along with central circulation core for ease of access.

vertical greeneries are added in each floor near the AHU to collect good quality air and for breakout spaces.

Fig. 12 : built form development with schematic view

d. Architectural design

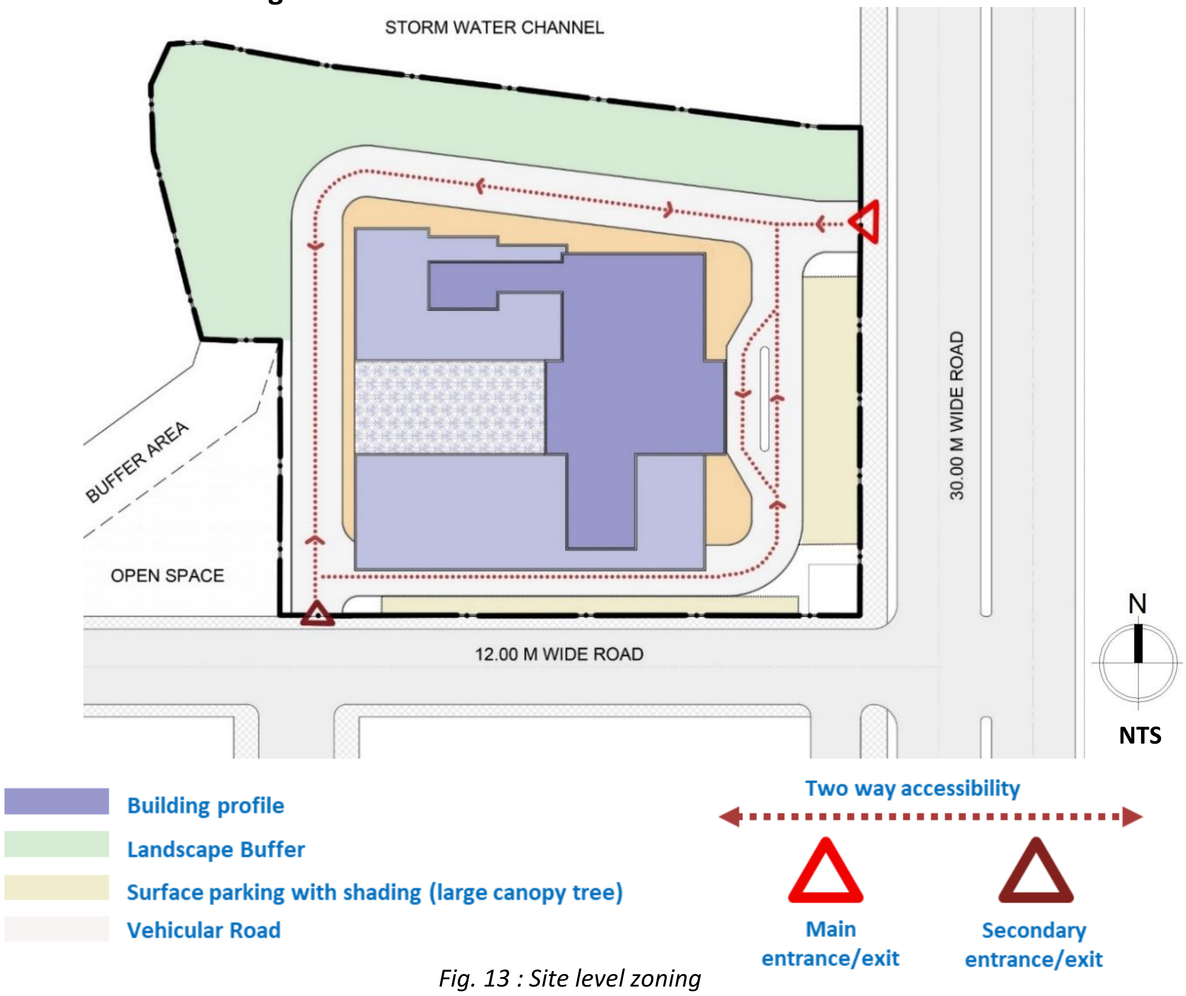


Fig. 13 : Site level zoning

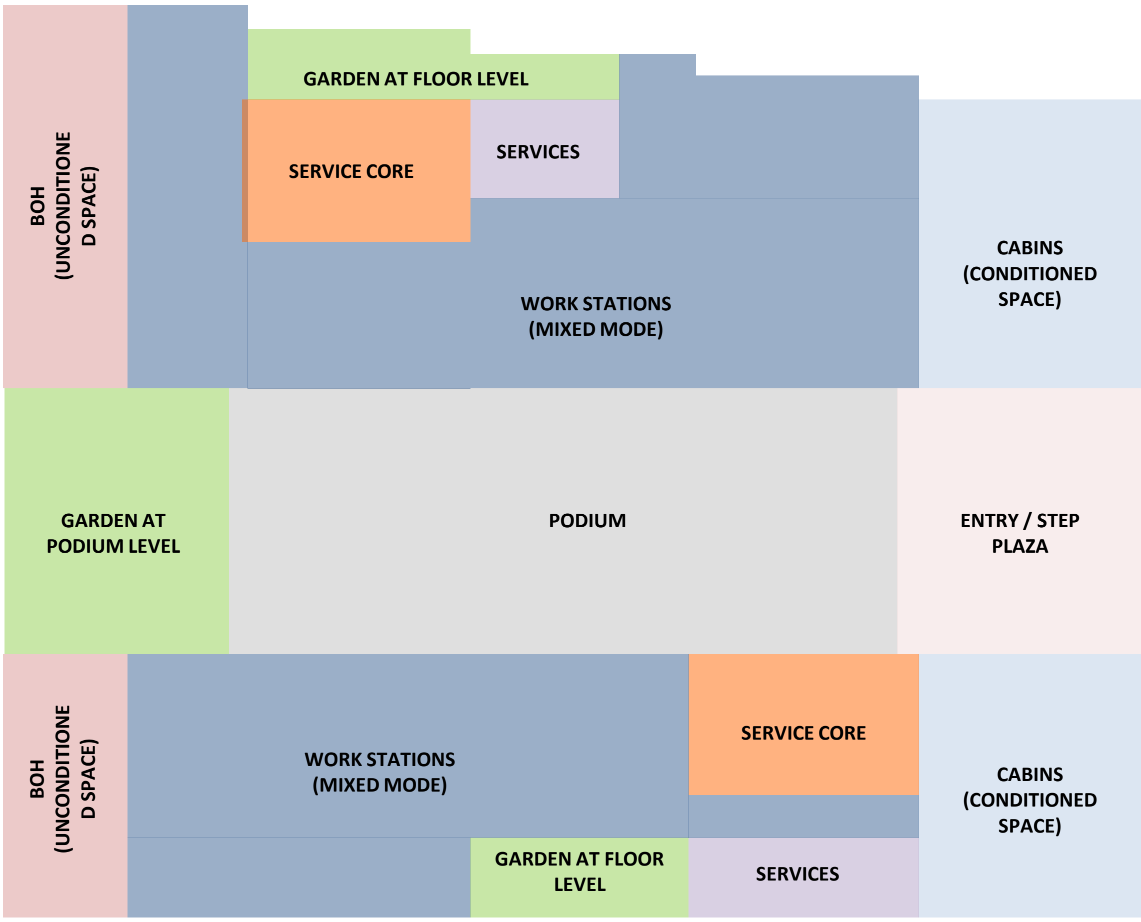


Fig. 14 : Floor level zoning

The design process was attempted as a ***synergy between nature, people(context) and the built environment***. The preliminary zoning was developed at the ***site and building level*** respectively to merge the respective bylaws/guidelines, spatial requirements and built environment dynamics.

At ***site level zoning***, priority is given to the entrances from the main and secondary road followed by the optimization of the building footprint, surrounding driveway for better circulation around the footprint with fire tender movement, optimum surface parking and integrated landscape management for outdoor thermal comfort, riparian ecosystem (biodiversity), outdoor activities and induce biophilia. ***Building level zoning*** is additionally categorized in two types – ***floor wise*** zoning / vertical zoning and ***floor level*** zoning / horizontal zoning.

As per the form development, the building have two wings "***Wing A and Wing B***". Wing A faces South towards secondary road and Wing B faces North towards buffer area. Different departments are incorporated in each wing on particular floors as per the ***requirements*** from the project partner and their ***preferences for placement***, was given the major priority to develop the ***floor wise zoning*** Furthermore, in **floor level zoning**, preferences were given to the spatial arrangement along with the ***horizontal and vertical connectivity's*** (service core, bridges, single flight staircases in central area, etc.) which are illustrated in architectural floor plans.

While doing the ***spatial zoning*** (cabins, workstations and BOH areas), space conditioning scheme (conditioned, mixed mode and unconditioned areas) was developed parallelly which is explained as ***'space and ventilation index'*** in all the floor plans. In addition to this, ***common activities*** like gym and yoga are placed on ground floor and restaurant with kitchen, multi-purpose hall and guest rooms are provided on sixth floor to maintain the privacy, functionality and energy usages.

In each floor, holistic consideration was laid in spatial allocation e.g. conditioned spaces (cabins, cubicles, guest room, conference room etc.) ***on the east***, services and shared function (toilet, printing, pantry) ***on the west*** and the ***central areas*** for collaborative open plan workspaces, meeting room and breakout spaces as per the **pre design analysis** for more nuanced approach for ***energy optimization, thermal comfort and daylight*** etc. along with the integration of vegetation to benefit the ***indoor environment quality and induce biophilic setting***.

e. Landscape & Ecology

Landscape was envisioned as an ***integrated aspect of the built environment*** to foster environmental sustainability, outdoor thermal comfort, activity and self sustainability. So, the strategies are been developed at site level and the respective building levels to ***induce biophilia*** while facilitating ***enhanced IEQ, activity quotient*** and ***socio physical - socio spatial livabilty***.

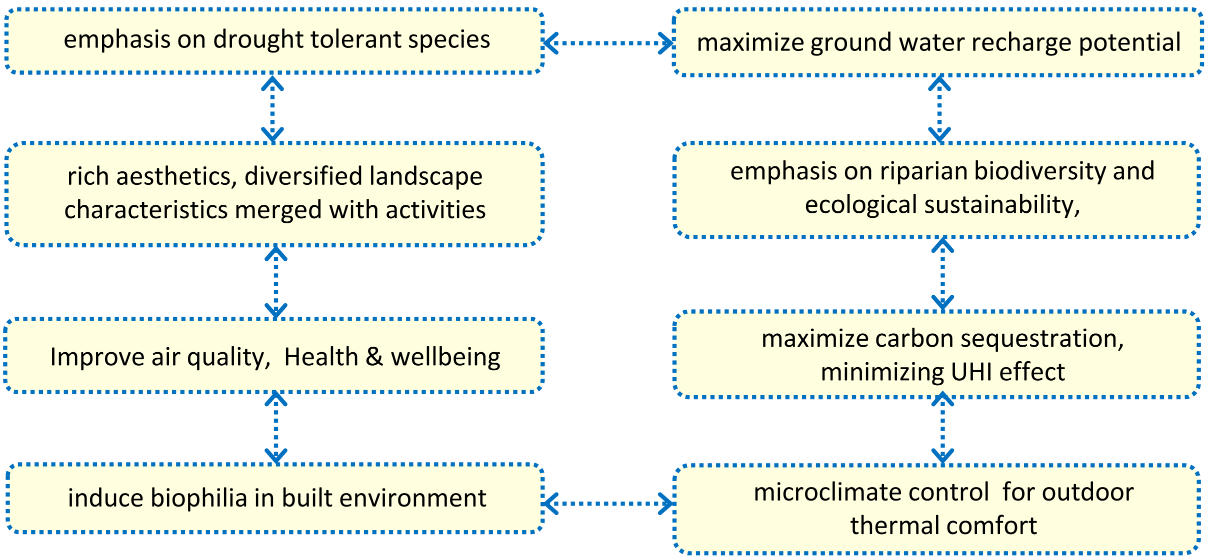


Fig. 15 : Projected landscape strategies for built environment sustainability (refer Annexure sr. no. 6d)

f. Architectural Drawings

Space Index (First Floor)

1. Staircase
2. Lift
3. Passage
4. Electrical room
5. AHU room
6. Store
7. Pantry & dining
8. Garden
9. Toilet
10. Handicapped toilet
11. Ladies toilet
12. Gents toilet
13. Printing & stationery area
14. Cabin
15. Cubical
16. Staff area
17. Executive cabin
18. Meeting/ discussion area
19. Steps to upper floor
20. Reception/ waiting area
21. Step plaza
22. Podium
23. Landscape court

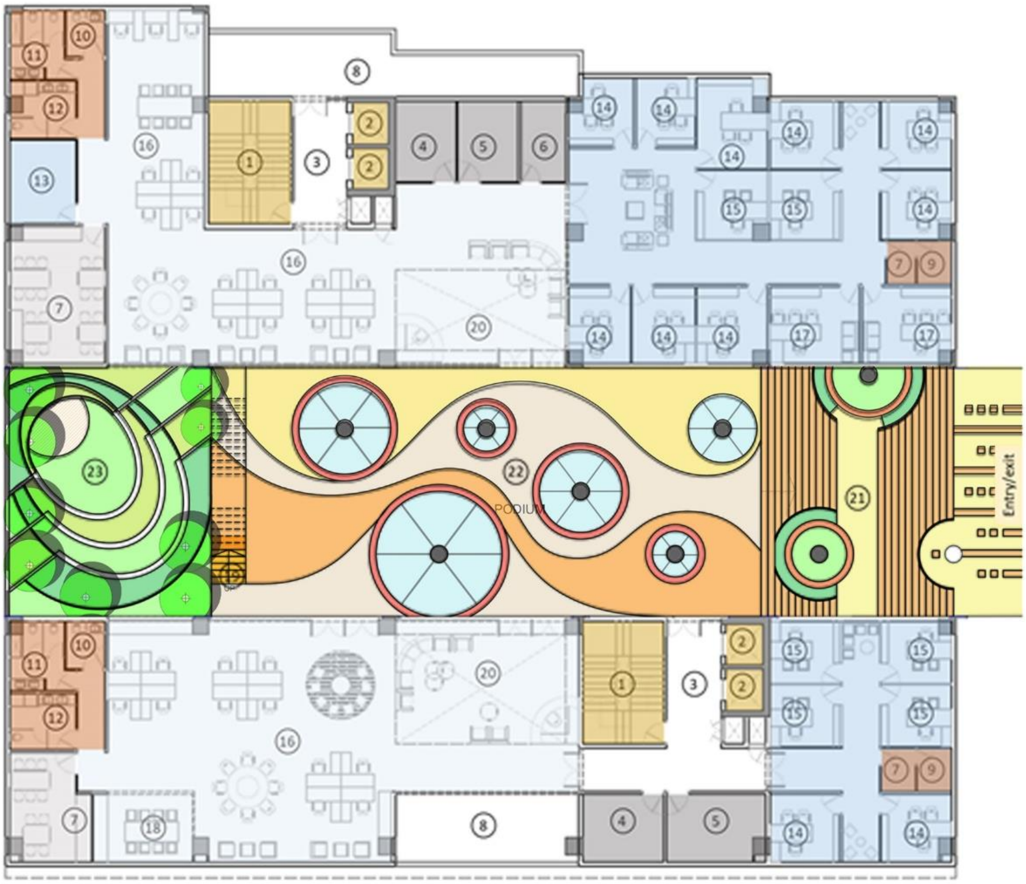


Fig. 16 : First Floor Plan (for podium details see annexure 6b)

N

NTS

Ventilation Index

- Pressurization
- Unconditioned but Naturally ventilated
- Mixed mode
- Naturally and Fan-forced ventilated
- Mechanically / Naturally ventilated
- Conditioned

N

NTS

Index (second floor)

1. Staircase
2. Lift
3. Passage
4. Electrical room
5. AHU room
6. Store
7. Pantry & dining
8. Garden
9. Toilet
10. Handicapped toilet
11. Ladies toilet
12. Gents toilet
13. Printing & stationery area
14. Cabin
15. Cubical
16. Staff area
17. Executive cabin
18. Meeting/ discussion area
19. Steps to upper floor
20. Steps to lower floor
21. Waiting area
22. Connecting bridge

(Note: to refers other floor plan details see annexure sr no. 6b)

Fig. 17 : Second Floor Plan

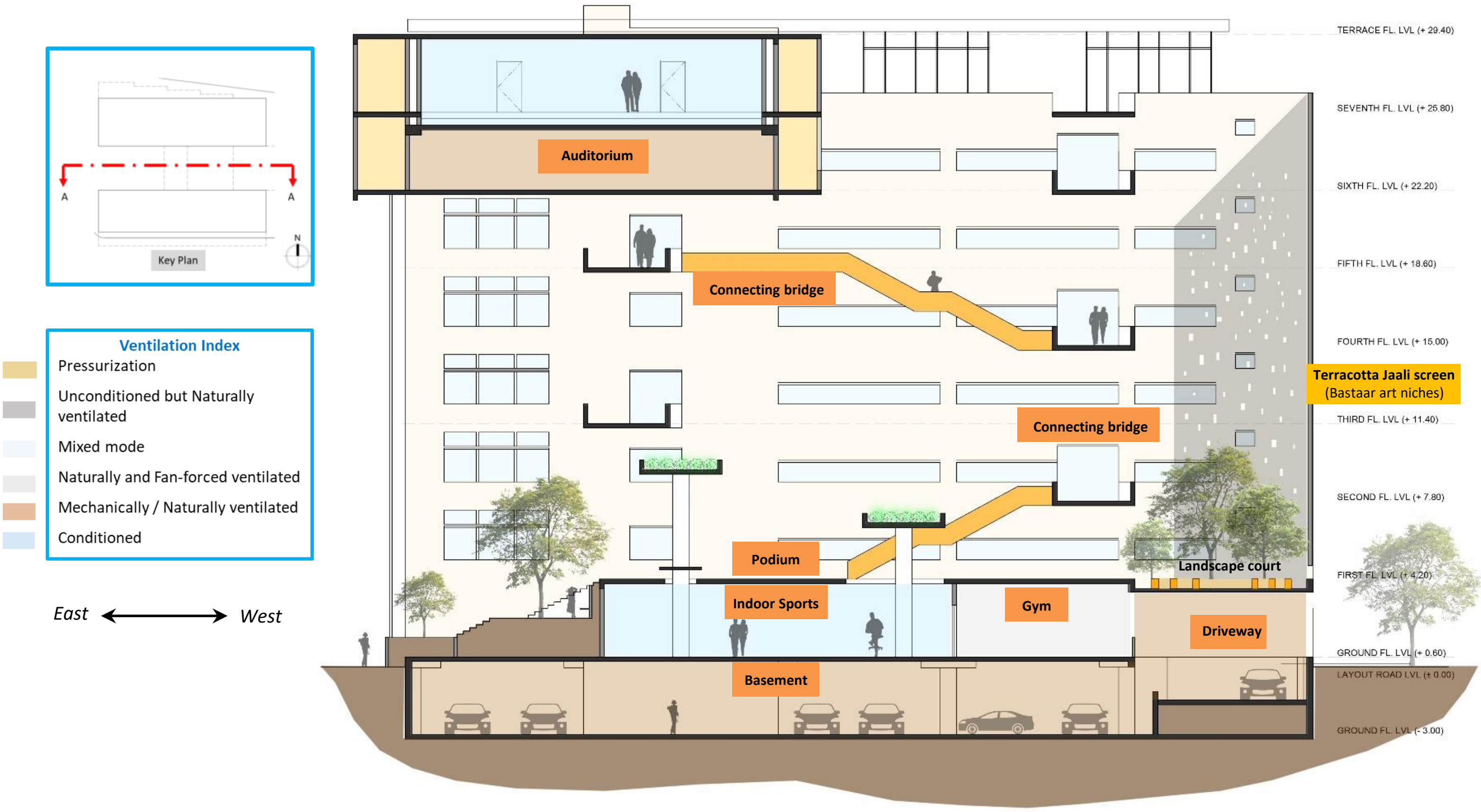


Fig. 18 : Sectional Details (for other sectional details refer Annexure sr. no. 6c)

Fig. 19 : Elevational Details (West side)

Fig. 20 : Roadside view of the proposed Sarda Headquarter Building

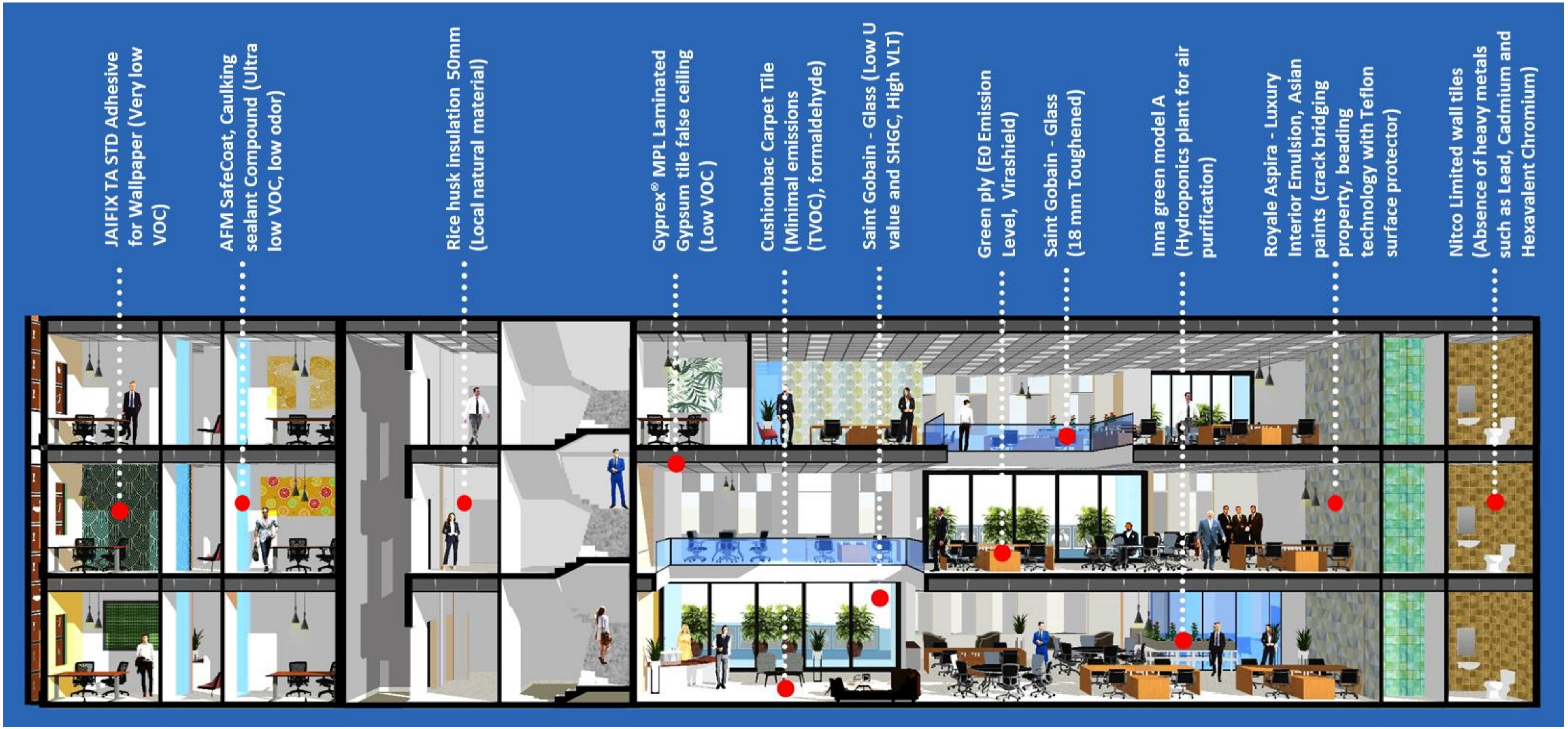


Fig. 21 : Sectional Perspective of the building showing the details

Fig. 22 : Site level plan with landscape details

(For Plantation detail see annexure sr. no 6d)

g. Shading Devices

To analyze the shading devices and their type, two major categories are considered and accordingly Raipur's climate is divided into ***Summer months*** (From December to June) and ***Winter months*** (From June to December). In summers, ***heat reduction and shading*** are the most important objective. Therefore, the sun position is tabulated as shown in table above, along with maximum office hour timings during sunshine hours (9am-6pm) for two important days i.e. ***21st March (Equinox)*** and ***21st June (Summer solstice)***. The timings at which shading is required are coloured in the table 5 while the timings at which the shading is provided is highlighted with dotted line. (*Kindly refer the Annexure sr. no. 6e for details of shading device).*

Table 5 : Solar movement analysis for shading devices (21st March & 21st June)

21st March							21st June						
HSA=Azimuth angle - Window orientation							HSA=Azimuth angle - Window orientation						
Time	Azimuth	Altitude	North (0)	East (90)	South (180)	West (270)	Time	Azimuth	Altitude	North (0)	East (90)	South (180)	West (270)
9	107.89	39.38	107.89	17.89	-72.11	-162.11	9	77.79	47.57	77.79	-12.21	-102.21	-192.21
10	119.05	52.24	119.05	29.05	-60.95	-150.95	10	79.28	61.29	79.28	-10.72	-100.72	-190.72
11	138.44	63.26	138.44	48.44	-41.56	-131.56	11	77.67	75.03	77.67	-12.33	-102.33	-192.33
12	173.30	69.20	173.30	83.30	-6.70	-96.7	12	20.01	87.41	20.01	-69.99	-159.99	-249.99
13	-147.61	65.93	212.39	122.39	32.39	-57.61	13	-76.77	76.79	283.23	193.23	103.23	13.23
14	-123.96	56.02	236.04	146.04	56.04	-33.96	14	-79.34	63.07	280.66	190.66	100.66	10.66
15	-110.89	43.56	249.11	159.11	69.11	-20.89	15	-78.06	49.33	281.94	191.94	101.94	11.94
16	-102.46	30.15	257.54	167.54	77.54	-12.46	16	-75.59	35.70	284.41	194.41	104.41	14.41
17	-96.06	16.36	263.94	173.94	83.94	-6.06	17	-72.34	22.26	287.66	197.66	107.66	17.66
18	-90.55	2.60	269.45	179.45	89.45	-0.55	18	-68.26	9.13	291.74	201.74	111.74	21.74

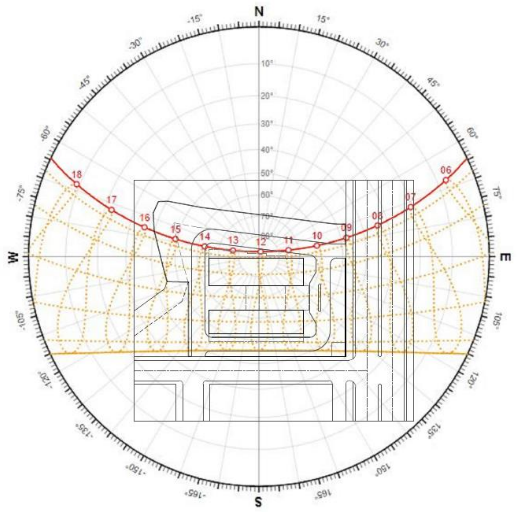


Fig. 23: Sun path diagram

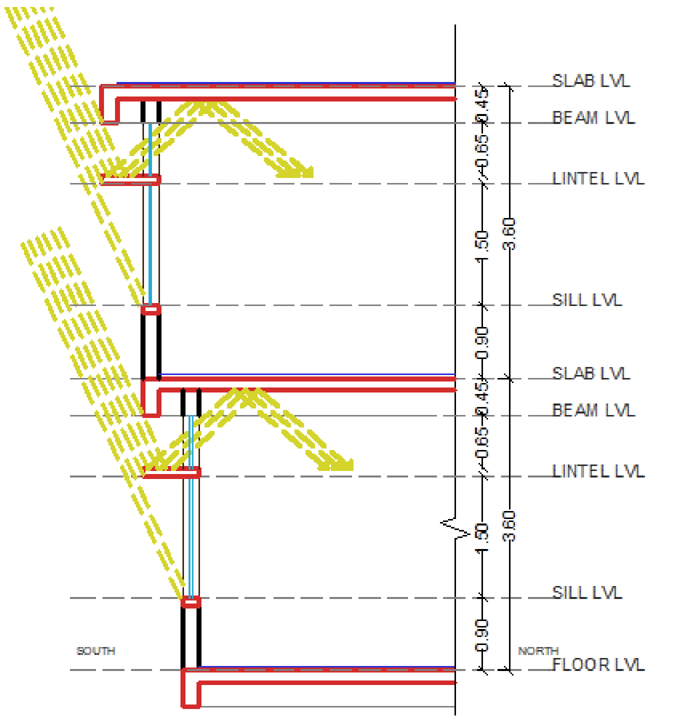


Fig. 24: Horizontal shading device and self shading in South façade with Light shelf

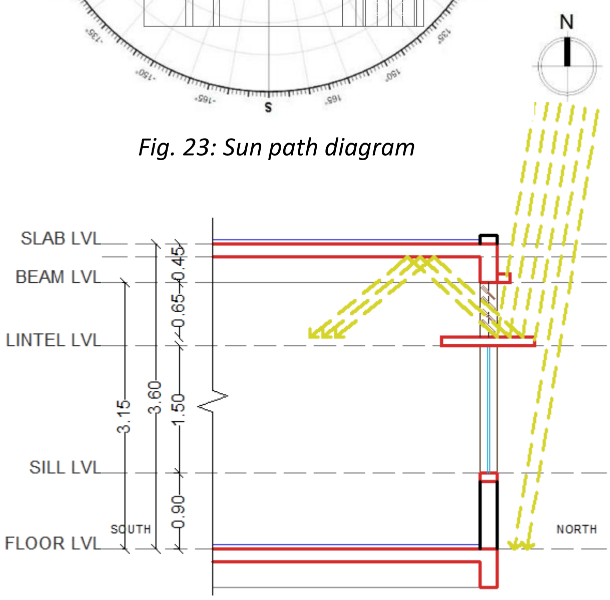
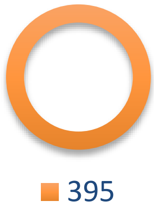


Fig. 25: Horizontal shading device in North façade with Light shelf

h. Energy Performance *(For detailed analysis refer Annexure sr. no. 8b)*



Measurement – For the base case design, the building was designed with no passive strategies, conventional building materials and 100% HVAC. The EPI calculated for the base case was 395 kWh/m2/year. The base case was also simulated without any HVAC (fully naturally ventilated) and the resultant EPI was 140.5 kWh/m2/year.

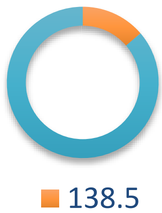
Zoning – The zoning refers to the segregation of internal spaces based on their functionality. Due to this the ventilation and lighting provided will be space specific. After the ventilation based zoning into conditioned (29.1%), unconditioned (20.9%) and mixed-conditioning (50%) spaces, the EPI reduced to 253 kWh/m2/year.

Building Material – 9 different wall assemblies consisting of the 3 locally available and viable materials were simulated as regular, cavity and insulated walls. The 275mm insulated AAC Wall was selected and applied which resulted in an EPI reduction of 5.5 units to 236.5 kW/m2/year.

Roofing and Rooftop Shading – 5 different roof assemblies consisting of combination of concrete slab, asphalt, fiberboard, XPS (Extruded polystyrene insulation) were simulated against the base case (220mm RCC Slab). The 230 mm Flat Slab with solar PV panels on top was applied and the EPI reduced to 230 kWh/m2/year.

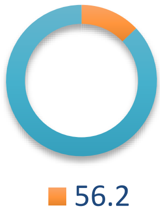
Window Glazing – 3 of each double and triple glazing window compositions were simulated against the base case of 6mm clear single glazing. The selected 3mm/ 13mm Argon filled Low E triple glazing was provided. The EPI decreased to 224.3 kWh/m2/year.

Window Shading – The building was simulated with the selected shading i.e. 1m projected louvers. However during lighting simulations, after application of lighting control, the projected louvers were found to decrease the useful daylighting resulting in an increase of about 40% in the lighting energy consumption. Therefore, after re-evaluation, 0.5m overhang were selected for the project that increase only 17.15 % of the lighting energy load. The total EPI after applying shading is 222 kWh/m2/year.



HVAC System– The HVAC system adopted was VAV Water cooled (absorption) chiller. The EPI reduced considerably to 138.5 kWh/m2/year.

Lighting – The base case for lighting used the best practice lighting having 15 W/m2 power density and no lighting control. Space specific lighting as per ASHRAE 90.1 was incorporated along with lighting controls in all areas (with LPD between 4.6-11.5 W/m2) reducing the EPI to 56.2 kWh/m2/year.



Eco-Sensitive Accessories – Energy star labelled equipment can be considered for the office to reduce the equipment load and increase the sustainability. The minimum energy efficiency of a computer as compared to a regular one is 40% for energy star labelled products. In addition to the Energy Star label, EPEAT (Electronic Products Environmental Assessment Tool), run by the Green Electronics Council, rates computers based on more than 50 energy-efficient criteria. If the same is applied to the project, the EPI can be further reduced to 54.5 kWh/m2/year.

Table 6: Energy consumption breakup for base case and proposed case

Typology	Heating (kWh)	Cooling (kWh)	Interior Lighting (kWh)	Exterior Lighting (kWh)2	Equipment load	Fans (kWh)	Pumps (kWh)	Heat Rejection (kWh)	Total (kWh
Base Case	2681.28	682,785.44	484,083.60	400.02	170,586	267,148	335,715	92,814.50	2036214
Proposed Building	2.49	140652	209557.2	400.02	8793.7	4999	8297.9	0	372702.8

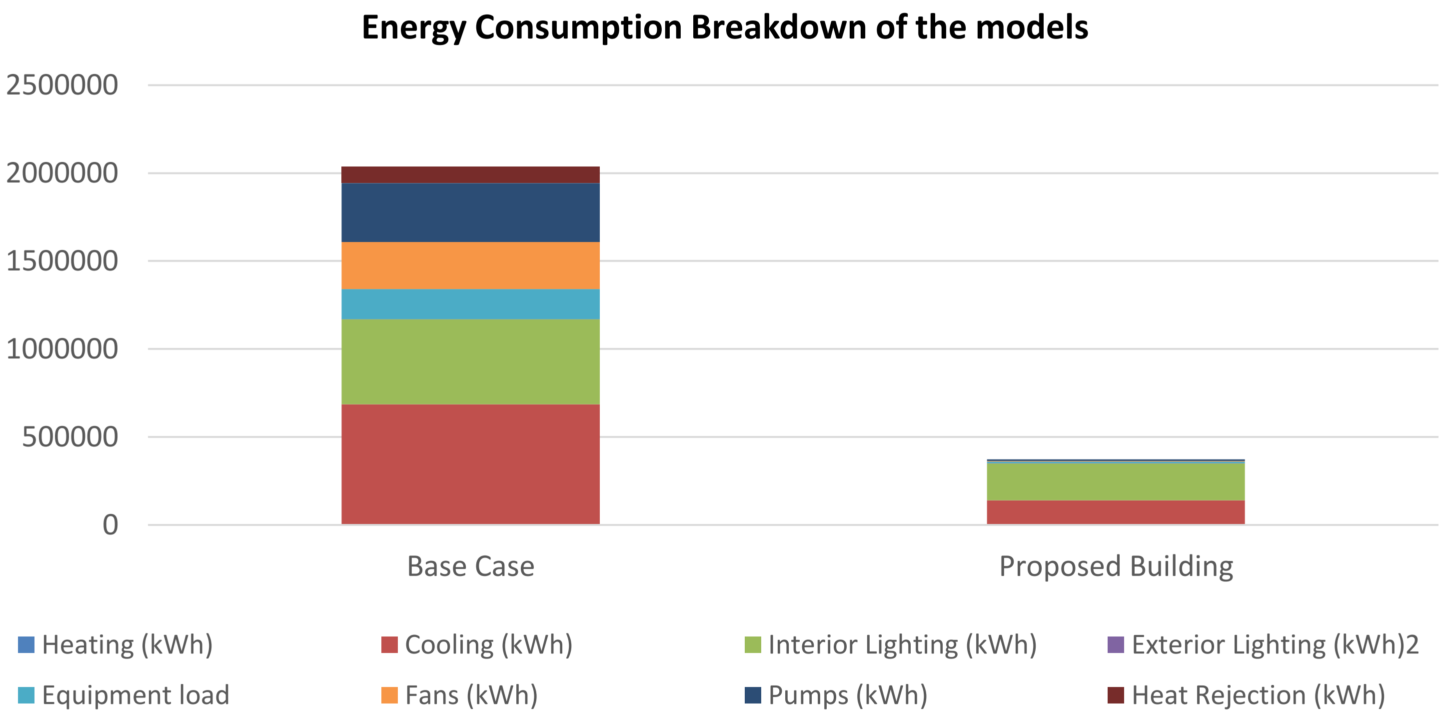


Fig. 26: Energy Consumption Breakdown of the Building

i. Water Performance - *(For detailed analysis refer Annexure sr. no. 12)*

Base Case

Table 7: Base case water calculation a) Per capita water requirement; b) Water requirement and STP capacity calculation; c) Water consumption per day

Utility	Flow Rate / Water Consumed	Duration	Daily Use per Person	LPCD	%age of consumption
Drinking	3L	-	-	**3**	11.070
Water Closets	6LPF	1 Flush	1	**6**	22.140
Urinals	4LPF	1 Flush	2	**8**	29.520
Health Faucet	4LPM	0.25min	1	**1**	3.690
Faucet/Taps	8LPM	0.25min	4	**8**	29.520
Kitchen Taps	8LPM	0.25min	6	**12**	44.280
Showerhead	10LPM	7 min	0.1	**7**	25.830
Total				**45**	

No. of Persons	Total Water Consumption	Water Consumption - Litre / Day	
		Domestic	Flushing
Water Requirement		LPD	LPD
Total	13030	**7855**	5175
STP Capacity (80% of Domestic + 90% of Flushing + 20% extra)			
Total Capacity		**13129.8**	

Total Daily Water Requirement		
Domestic Use	7855	LPD
Flushing Use	5175	LPD
Horticulture	1765	LPD
HVAC	0	LPD
Total	**14795**	**LPD**

Irrigation Use	
L/m^2	1
Area m^2	1765
Max LPD	1765

Proposed Case

Table 8: Proposed case water calculation a) Per capita water requirement; b) Water requirement and STP capacity calculation; c) Water consumption per day

Utility	Flow Rate / Water Consumed	Duration	Daily Use per Person	LPCD	%age of consumption
Drinking	3L	-	-	**3**	11.1
Water Closets	4LPF	1 Flush	1	**4**	14.8
Urinals	0LPF	1 Flush	2	**0**	0.0
Health Faucet	2LPM	0.25min	1	**0.5**	1.8
Faucet/Taps	5LPM	0.25min	4	**5**	18.5
Kitchen Taps	6LPM	0.25min	6	**9**	33.2
Showerhead	8LPM	7 min	0.1	**5.6**	20.7
Total				**27.1**	

No. of Persons	Total Water Consumption	Water Consumption - Litre / Day	
		Domestic	Flushing
Water Requirement		LPD	LPD
Total	7455.5	**5903**	1552.5
STP Capacity (80% of Domestic + 90% of Flushing + 20% extra)			
Total Capacity		**7343.58**	

Total Daily Water Requirement		
Domestic Use	5903	LPD
Flushing Use	1552.5	LPD
Horticulture	882.5	LPD
HVAC	4000	LPD
Total	**12338**	**LPD**

Irrigation Use	
L/m^2	0.5
Area m^2	1765
Max LPD	882.5

The water requirement was calculated based on the current and future occupancy. Table 7 shows the base case, which was formulated based on standard requirements from NBC 2016. Table 8 shows the proposed case, in which the overall water requirement is reduced through the use of efficient fittings and fixtures such as waterless urinals, water efficient taps, etc. The water requirement is further offset by rainwater harvesting, recycling and reusing the wastewater. **Thus net zero water can be achieved by using water efficient fixtures.**

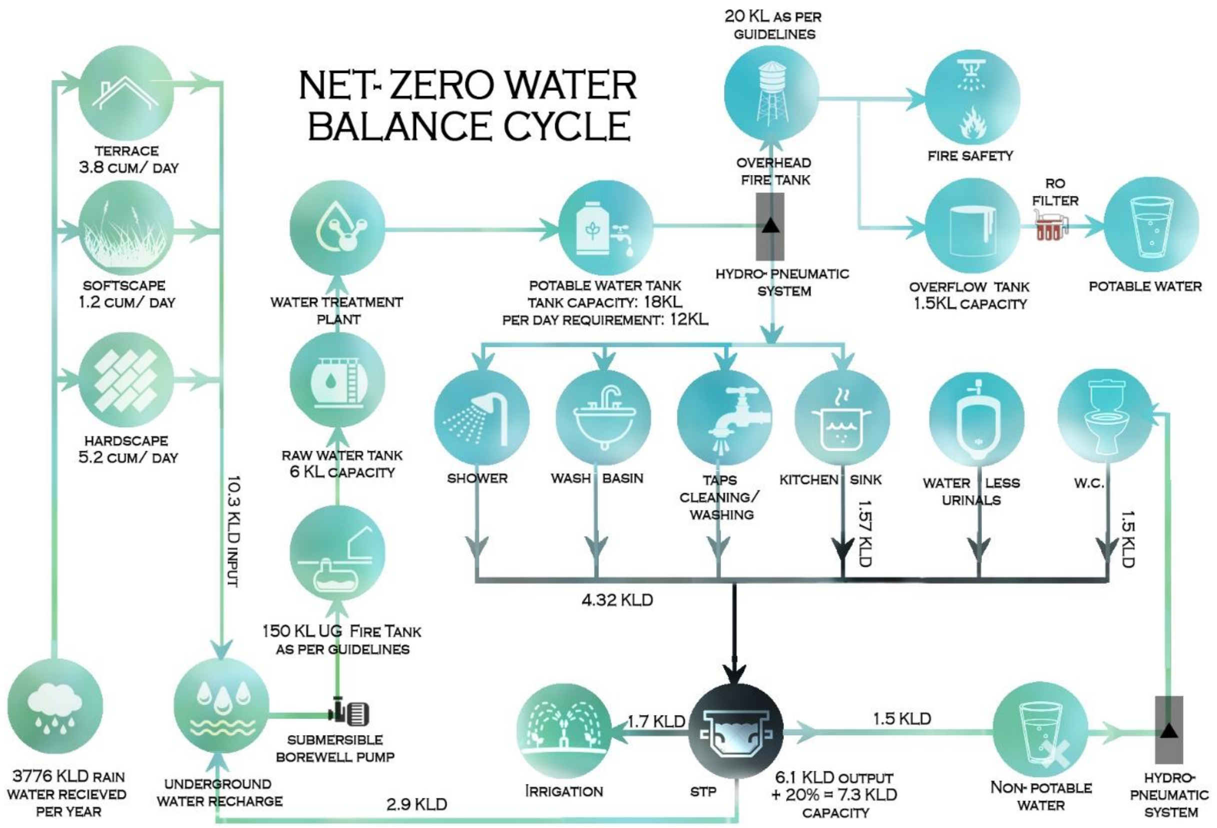


Fig. 27 : Water cycle diagram identifying uses and sources of water along with reuse pathways

j. Engineering and Operation –

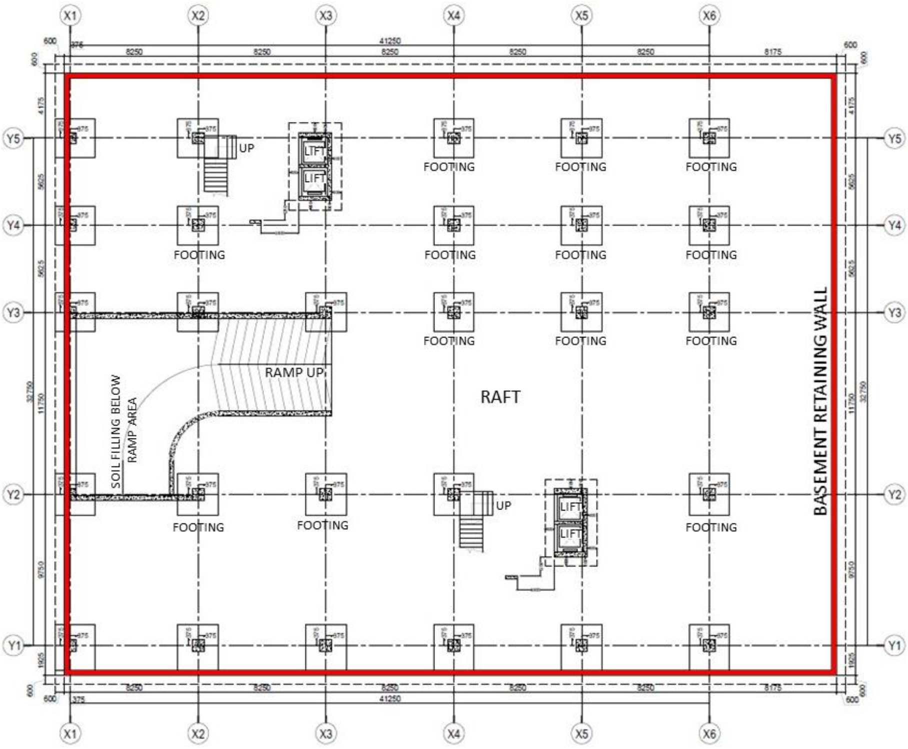


Fig. 28 : Basement structural plan (Footing & Centerline)

i. Structural Details –

To have the flexibility in internal planning, clear floor to floor height, large open span, etc., the building is designed in a structural grid of 8.25 m in longer length of the building as shown in figure 26, 27, 28. Flat slab technique is compared with RCC frame structure the and it ***proves beneficial*** to achieve more clear height with minimum floor to floor height, flat slab with drop panel is designed and for structural stability beams are provided at periphery, near staircase and cut-outs. Details of slab and drop panel is shown in figure 29.

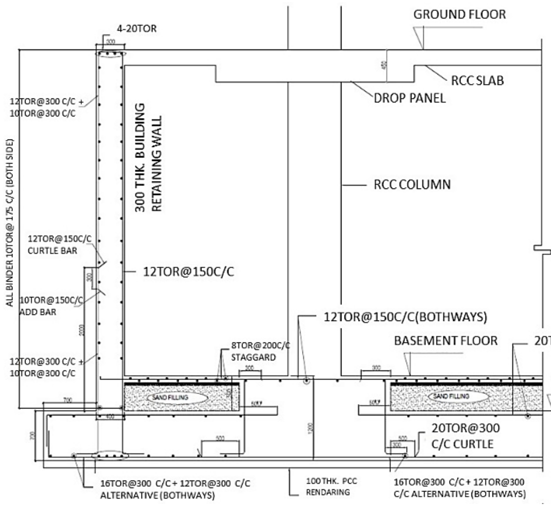


Fig. 29 : Raft and retaining wall detail

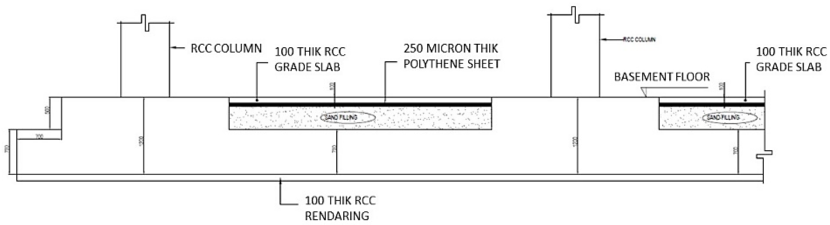


Fig. 30 : Raft detail

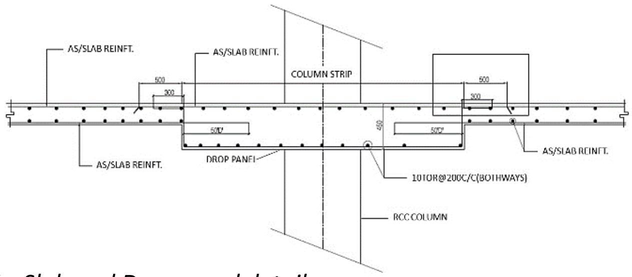


Fig. 31 : Slab and Drop panel detail

ii. Building Automation and Control System –

The building automation and control system is ***integrated*** in the Office building to maintain the control of building's environment, to operation the installed systems as per the occupancy or energy demands, to monitor and resolve the performance of the systems and services (like fire detection, smoke detection, pump working, etc.). The designated room is provided in ***Basement floor*** to address, monitor, operate and control the facilities like lifts & mechanical systems, plumbing, electrical systems, HVAC systems, lighting control, security and surveillance, vents or exhaust systems, fire alarm and other emergency systems, etc.

Fig. 32: Building Automation and Control System

[Source : Google images]

iii. Minimizing of Waste of Material and Energy –

To avoid the material and energy ***wastage*** and to reduce the same, many strategies are adopted in different forms such as ***environmentally friendly*** materials are used which are locally available and contains less VOC values, building envelope is designed suitable to climatic considerations and requires less energy, glazing optimizations to reduce ***glare and heat gain***, passive building design to maintain indoor comfort, optimised HVAC system design which uses less energy and affordable to operate and maintain and use of ***energy efficient*** lighting and autonomous lighting.

[Source : Google images]

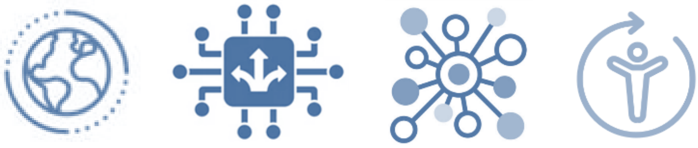
k. Scalability and Market Potential –

The USP's of the project can be defined as the ***two tier*** approach (Vertical and Horizontal tier) through a integrated design framework.
The ***Vertical tier*** may address as – ***Net Zero Office building*** as per ***Energy, Water, Waste***;

[Source : Google images]

The secondary or the ***horizontal tier*** may be defined with –

- ***climate responsive*** design model***;***
- ***flexible*** spatial planning with ***universal*** design guidelines;
- ***optimized metrics*** for thermal, visual and acoustic comfort for the occupants;



[Source : Google images]

- ***technological*** interpretation in energy optimisation, health and wellbeing;
- ***promotion*** of local material with a ***emphasis*** on waste or **recycling**, ***indigenous*** art-culture, craftsmanship;
- focused ***environmental stewardship*** through the life cycle.

[Source : Google images]

So, this two tiered approach will create multilayered dynamics regarding scalability and market potential.

i. Market analysis and target population

As per the design requirements given by the project partner, the office is specially design for the ***employees*** of Sarda group only who currently resides in the city periphery. The project aimed for a ***flexible spatial morphology*** with ***open plan workplace*** and ***flat slab*** technique to facilitate scalability, modularity with ***minimum negative spaces*** while maximizing the potential for the ***future expansion***. The types of ***transportation*** used by the employees are two or four wheeler, local auto-rickshaw and bus services, in a ***well connected transit network*** within the city.

The ***net zero proponent*** of the office building will cater the major selling attributes, the ***climate responsive integrated framework*** can be used as a ***model with the optimized metrics for thermal, visual and acoustic comfort*** to ***replicate a flexible model*** for the ***similar climatic zone***s or in case of ***different climatic*** zone the framework can used as ***tool to identify*** the ***appropriate solution*** to achieve ***net zero efficiency adjusted*** to the ***occupant capacity*** and the presiding ***context at the micro-macro level.***

All the areas which have the Composite climatic zones in Indian Context or similar characteristics of Hot and Dry Climate are the proposed target areas for the design replication.

Material Scalability can be triggered by the use of ***locally available***/***resourced*** material with an emphasis on ***recyclable content, healthy indoor*** guidelines. Envelope and other materials can be ***alternated*** as per ***resource availability*** in ***different context*** with an ***optimized assembly*** selection based on the ***heat transfer properties*** and ***cost*** proponent. ***Translation*** of ***indigenous cultural attributes (material, craftsmanship)*** into the built environment can ***trigger*** the ***niche market***, ***scaling up the target population.***

Environmental stewardship with an emphasis on ***energy optimisation, zero waste site***, promoting ***landscape and ecological sustainability*** to reduce the ***vulnerability (socio-physical-economic)*** and with ever increasing ***environmental threat*. So this ***proactive actions*** through ***integrated design approach*** may trigger associated ***stakeholders*** to develop a better ***value chain model and knowledge base*** for ***long term sustainability.***

ii. Social and economic background

Raipur is centrally located within the state boundaries serving as a ***regional hub for trade and commerce*** for various agricultural and forest products. The main occupation in Raipur is agriculture, rice and saw mills. ***Chhattisgarh state*** has huge influence of ***culture on lifestyle***. The two major art form near Raipur is ***Gond paintings*** and Bastar art. ***Bastar art*** can be seen in the form of paintings, murals, miniatures, wooden craft, iron craft and ***Dokra craft*** which is made by casting bell metal (brass and bronze).

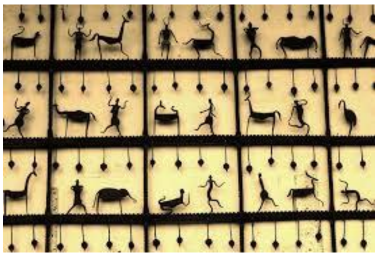


Fig. 33 : Iron craft of Bastar art

[Source : Google images]

iii. Technologies and Materials

There are many ***natural resources*** available in the state. Plantation wood which is also considered as ***"green"*** wood products is available at the periphery of Raipur. It has ***rich mineral*** resources too. Cement, mining, steel, aluminum and power are the ***key sectors***. In additional to this ***handcrafted*** wood, iron, terra cotta and bell metal is also available. Due to the large agricultural production of rice, ***rice husk*** is readily available.

iv. Environmental issues

The major environmental issue of Raipur is the ***air quality***. The AQI of Raipur is above 300 which is considered as poor. Therefore, plantation is provided which will act as ***carbon sink*** and garden spaces on upper floors also which will intend to facilitate ***purified air*** to internal office spaces.

v. Ideas for addressing the context and market

To incorporate the ideas to address the ***context and market***, the considerations such as ***Iconic*** building design, More ***interactive*** space design, Implications of ***local art***, Use of locally available materials and design of ***landscaping*** at various levels is carried out.

[Source : Google images]

I. Resilience

Team Mrittika attempted several measures to make the building adaptive and make it ***resilient*** from natural disasters, environmental conditions such as climatic change, hazards and the following measures are considered–

Earthquake resilient design – Raipur lies in ***Earthquake Zone-II***, which have the lowest level of seismic vulnerability, but structural design has been done to sustain the worst case scenario. Appropriate structural systems has been laid out with column and beam ties, sill and lintel level bands, peripheral beams even the ***RCC flat slab*** technique is adopted with column capital.

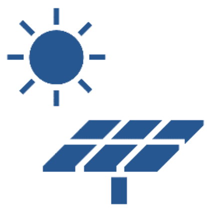
Flood resilient design – *No major flood* arises in the Raipur, but there may be water logging due to heavy rains and poor underground drainage system. Therefore, the entire layout is levelled along the road level (marked as +00 level in the drawings) which is almost 2 m higher than the contour level of the storm water channel abutting the site. The building is kept at stilt and minimum required plinth of 0.60 m provided to the entrance lobbies at ground floor.

Heat wave resilient design – To reduce the ***heat gain*** through building envelope, prior attention is given towards ***climate responsive*** passive design. Also, in case of building façade, ***optimized wall assembly*** with insulation and appropriate ***shading strategies*** in each orientation has been considered. While rooftop solar PV panel with truss system is adopted for the entire roof area.

Fire Safety services – To make the building resilient *during fire emergency*, fire safety services are adopted based on the mandatory requirement as per *NBC, Part 4* which includes the 6 m wide driveway around the building for fire tender movement, fire shaft, fire extinguisher, hose reel, yard hydrant in the surrounding area, wet riser, automatic sprinkler and detection system, manual call points, fire alarm systems, underground tank placed in the basement having the capacity of ***1,50,000 litres*** and overhead tank of ***20,000 litres***. In addition to this fire escape staircase within the span of 30 m travelling distance from end points and refuge area above 24 m height are provided.

Universal Design – The proposed building is a corporate office- self owned by the project partner. So, ***universal design*** aspects are considered in architecture design which includes ramp at entry points, disabled toilet on each floor, barrier free movement connectivity to upper floors through bridges and lifts etc.

Power Backup and water autonomy – The proposed building is designed to ***self sufficiency*** to meet the energy and water demands while running the mechanical system. In addition to that, DG backup is provided at designated areas. The energy generated from renewable sources are supplied to grid.



Renewable energy generation – Different strategies are adopted to generate the energy from renewable sources. It includes the Roof top solar PV, BAPV panels on west façade, ***Bio-methanation plant*** and ***waste to energy*** plant.
Four different cases are to calculate roof top energy generation with the placement of 752 panels on a truss structure. From the optimization, the panels inclination as per latitude, generates the annual energy of ***4,64,626 kWh***. While, 215 number of panels placed on west façade helps to generate ***80671 kWh*** of energy annually. (*The details of all the systems are given in annexure sr no 13.*)

[All the vectors are sourced from Google images]

m. Affordability

To achieve the affordability in terms of ***dead load, material, labour, construction cost and time***. Team Mrittika has taken two scenarios to fulfill the design requirements without compromising the structural aspects desired by the building and the clear floor to floor height of 3.00 m.

Scenario 1 (Base case) is *the* ***"Conventional RCC frame structure"*** in which the conventional frame structure is designed and provided with the floor to floor height of 4.20 m (Req. clear ht. 3 m+ Above ceiling services 0.45 m + Beam depth 0.75 m) and the total building height is 34.20 m.

Scenario 2 (Proposed case) is the ***"RCC flat slab with column capital"***, keeping the column grid similar as the base case but doing modification in structural design, the received floor to floor height is 3.60 m (Req. clear ht. 3 m+ Capital depth 0.45 m + Finishing below the capital 0.15) and the total building height is 29.40 m.
Therefore, from both the scenarios, proposed case helps to reduce the building height by 4.80 m which additionally helps to ***reduce the five aspects*** mentioned above. The cost reduction between the two scenarios is shown in cost estimation sheet.

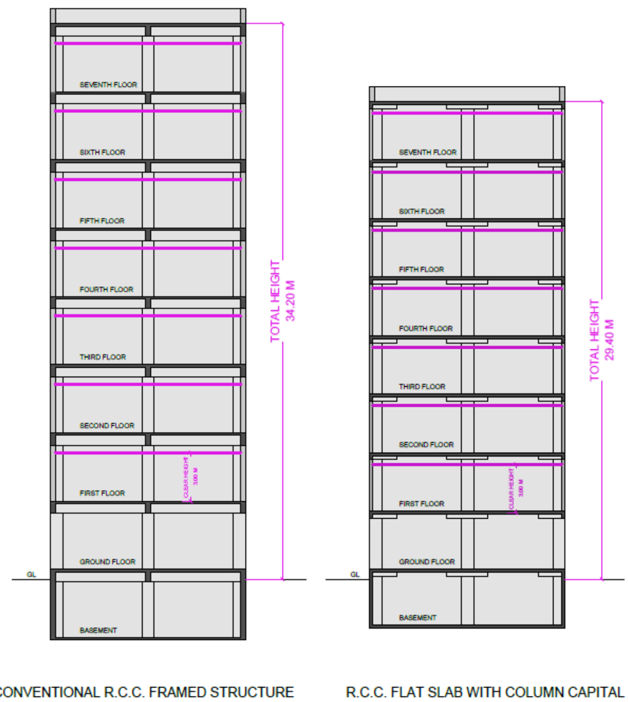


Fig. 34 : Structural system comparison

It is observed that due to the variation in building height and structural system as mentioned above, ***19% of cost reduction*** can be achieved. Kindly refer the annexure table no. 11 in which the cost comparison of one floor of particular building is given in brief.
Table no. 9 shows that with the increase of ***3.36 %*** cost per built up area helps to increase the ***building performance*** as compared to the base case.

Table. 9 : Project Cost Summary (For details, refer Annexure sr. no. 11 & cost estimation sheet)

Project Summary				
S.No.	**Particulars**	**Definition**	**Baseline Estimate (Project Partner / SOR basis)**	**Proposed Design Estimate (Market rates)**
			Amount (Rs Millions)	**Amount** (Rs Millions)
1	Land	Cost of land purchased or leased by the Project Partner	11.05	11.05
2	Civil Works	Refer Item A, Civil works in Cost of construction worksheet	208.00	210.63
3	Internal Works	Refer Item B, Civil works in Cost of construction worksheet	54.56	48.81
4	MEP Services	Refer Item C, Civil works in Cost of construction worksheet	71.14	85.22
5	Equipment & Furnishing	Refer Item D, Civil works in Cost of construction worksheet	57.66	59.51
6	Landscape & Site Development	Refer Item E, Civil works in Cost of construction worksheet	17.96	20.57
7	Contingency	Amount added to the total estimate for incidental and miscellaneous expenses.	30.96	32.03
		Total Hard Cost	**451.33**	**467.82**
8	Pre Operative Expenses	Cost of Permits, Licenses, Market research, Advertising etc	-	-
9	Consultants	Consultant fees on a typical Project	21.85	21.85
10	Interest During Construction	Interest paid on loans related to the project during construction	-	-
		Total Soft Cost	**21.85**	**21.85**
		Total Project Cost	**473.18**	**489.67**
		Total Project Cost per Sq.m of Built-up Area	**51,006**	**52,783**

n. Innovation

i. Architectural Innovation

The ***built form***, optimized based on the climatic consideration, daylighting, natural ventilation and heat transfer. The design was aimed to maximize the ***efficiency*** of the internal spaces by adopting an ***open plan*** workspace, cubicles with multifunctional areas. Each floors were facilitated with ***green pockets*** that could simultaneously serve as ***refuge areas*** in case of an emergency. Furthermore, the ***AHU*** was placed adjacent to the green pockets to ***ensure fresh air intake***. The circulation areas e.g. ***podium and bridges*** also added inbuilt breakout spaces like seating areas and coffee kiosks that will maximize the ***social cohesion***. Also, the ***multipurpose hall*** was designated in the top floor to expand the spatial ***functionality*** and enhance ***mutual shading*** potential.

ii. Visual and Physical Connectivity

Additionally ***3 tier connectivity*** is provided- ***vertically*** through staggered staircases, ***horizontally*** through ***alternate bridges*** and ***visually*** through ***internal cut-outs***.

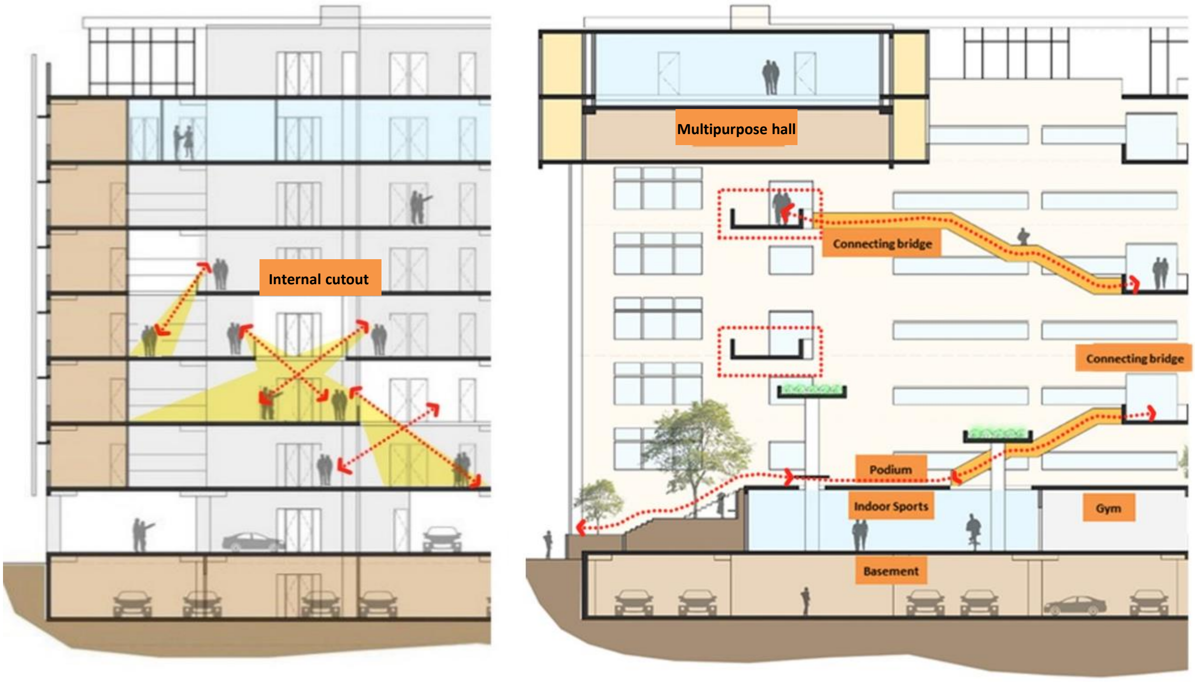


Fig. 35: Section of the building showing multi-functionality and connectivity

iii. Technological Innovation

Among the new technological features incorporated in the building such as lighting controls, smart fixtures (I.O.T based tech), the most innovative is the combination of the renewable energy sources used. Apart from the rooftop solar panels, technologically innovative methods such as BAPV panels and waste-to-energy generators were used. Disposal of both organic and inorganic waste through separate waste to energy generation systems helps attain a zero waste site.

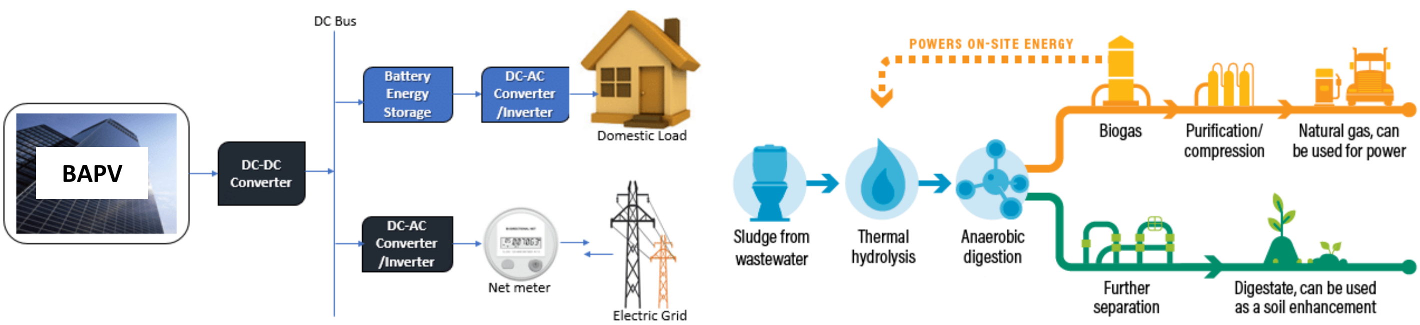


Fig. 36: a) BAPV to energy generation system and b) Waste to energy system

iv. Material Based Innovation

After simulating various materials and envelope assemblies, *a* ***275 mm insulated AAC block*** was used for the ***wall assembly***. Depending in the market analysis, ***rice husk*** was selected as the ***insulation***. Rice husk is a solution for both the construction and agricultural industries. In a state like Chhattisgarh where rice paddy farming is large scale, the excess rice husk generated need to be properly disposed off. Using rice husk for insulation purposes solves the ***disposal issue*** as well as provides a more ***eco-friendly and bio-degradable*** material for insulation. It offers good insulation potential since it does not burn easily and ***highly resistant*** to the moisture and fungal decomposition. Also, it ***decomposes slowly*** due to the rich silica content.

Fig. 37: a) loose rice husk obtained from agriculture, b) rice husk insulation board and c) cross-sectional view of the 275mm AAC wall showing the insulation board in the center.

v. Vegetation Based Innovation

For indoor plantation, the ***Innagreen model A*** device was adopted. It is an innovative product that can grow plants without any soil. It can be hung from the railing or walls or can be installed as a vertical garden or simply be set on the office table to improve the ***indoor environmental quality***. It consists of a grow box, metal frames for support, air pump, leca balls and a growing medium along with nutrient solution for proper plant growth.

Fig. 38: Innagreen plantation device

o. Communication

Team Mrittika has tried to convey their design process and ideas through the use of social media sites such as ***Instagram, Facebook and LinkedIn***. The idea was to engage with people and familiarize them with the concept of ***sustainability*** and ***net zero energy*** building so that more people will consider adopting the same.

Table 10. Social Media Analytics (refer annexure sr. no. 14)

Instagram: Total No. Of Followers – 48				
Topic	**Month**	**Posts**	**Views/Likes**	**Comments**
Team Introduction	Oct-Nov 21	2	23	0
Individual Introductions	Nov-Dec 21	10	100	1
Design Goals	Jan 22	1	39	0
Introduction to site	Feb 22	1	28	0
Total		14	190	1

Fig. 39: Instagram Profile
[Mrittika Spav (@mrittika7.spav) • Instagram photos and videos]

p. Health and Well-being

i. Day light and Visual Comfort

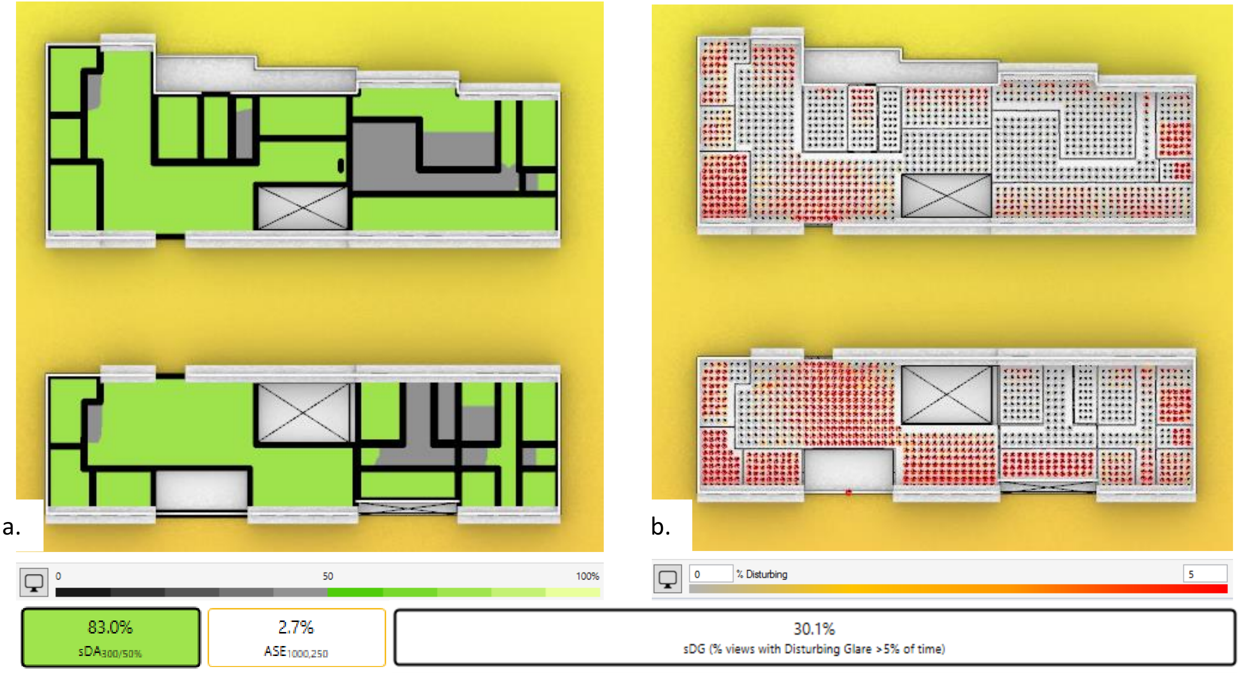


Fig. 40: a) Daylight autonomy and annual solar exposure, b) annual glare analysis (Simulated case: Second floor)

Not more than ***2.7% (ASE)*** of the total area will receive more than 1,000 lux for 250 hours each year. While, ***83%*** of the analyzed area (sample footprint) meets the minimum daylight illuminance level of ***300 lux for 50%*** of the operating hours per year, **achieving the parameters as mentioned in the Goals**. Also, only 30.1 % of the occupied area is exposed to disturbing views due to glare for more than ***5% of the hours per year*** between 7 am to 5 pm which can be eliminated by the use of ***internal blinds***.

(*additional details of daylight analysis are given in annexure sr. no*. 9)

Fig. 41: Daylight illumination on 21st June at 3 pm

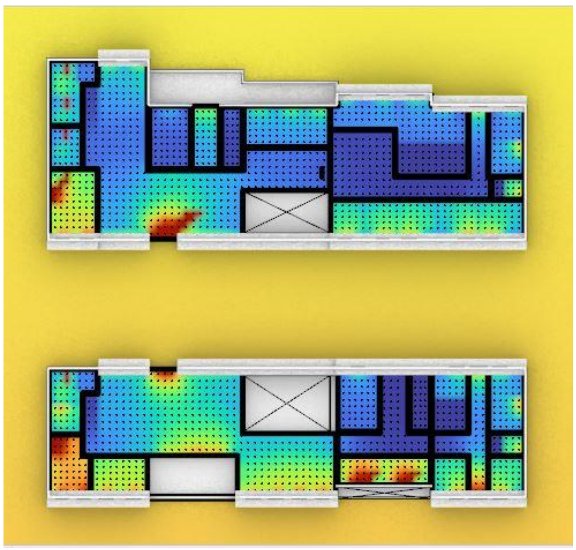
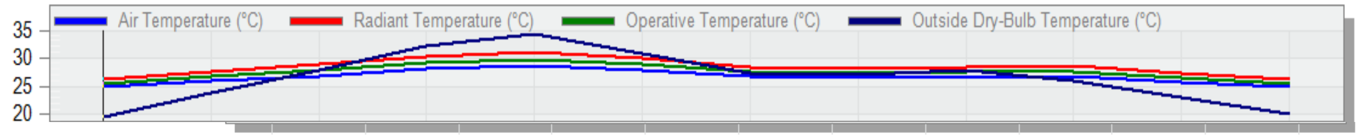


Fig. 42: Daylight illumination on 21st Dec. at 3 pm

(simulated case: Second floor)

ii. Indoor thermal comfort

Natural ventilation analysis-

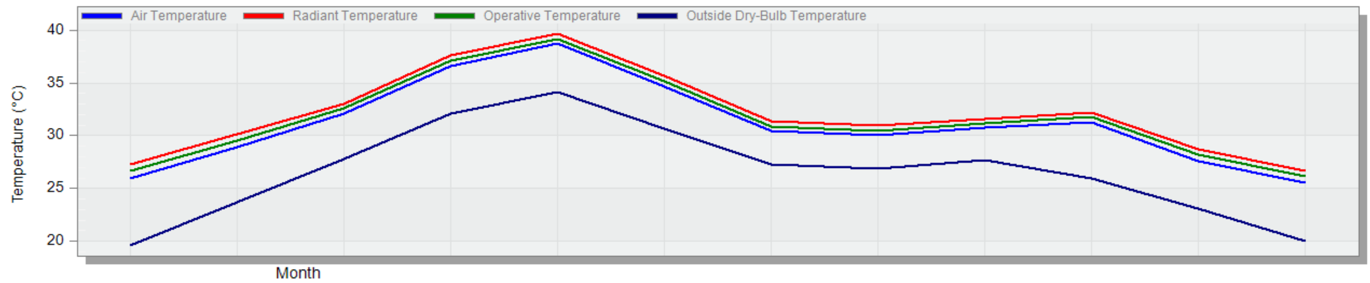


Month	2022	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature (°C)	24.91	25.99	26.75	28.01	28.53	27.68	26.75	26.42	26.57	26.66	25.67	24.88
Radiant Temperature (°C)	26.17	27.67	28.78	30.26	31.02	29.91	28.36	28.16	28.33	28.50	27.24	26.14
Operative Temperature (°C)	25.54	26.83	27.77	29.14	29.77	28.80	27.55	27.29	27.45	27.58	26.45	25.51
Outside Dry-Bulb Temperature (°C)	19.65	23.70	27.81	32.12	34.11	30.65	27.30	26.91	27.74	25.97	23.07	20.07

Fig. 43: Thermal Comfort analysis of Conditioned Spaces

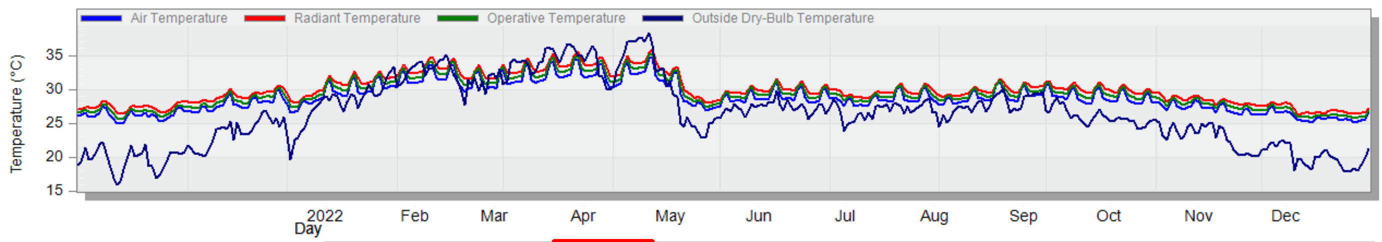
The indoor thermal comfort was checked for mechanically ventilated and naturally ventilated areas. The mechanically ventilated spaces maintained indoor thermal comfort temperatures at all hours.

W.R.T. the naturally ventilated areas, the spaces maintained thermal comfort 9 out of 12 months. During the months of April to June, the indoor temperature achieved was 2-4 deg. Celsius more than the upper thermal comfort temperature value (32 deg.)



Month												
Air Temperature (°C)	25.99	28.94	32.11	36.64	38.69	34.63	30.43	30.03	30.76	31.27	27.60	25.50
Radiant Temperature (°C)	27.32	30.11	33.03	37.58	39.63	35.63	31.33	30.95	31.58	32.20	28.76	26.72
Operative Temperature (°C)	26.66	29.53	32.57	37.11	39.16	35.13	30.88	30.49	31.17	31.74	28.18	26.11
Outside Dry-Bulb Temperature (°C)	19.65	23.70	27.81	32.12	34.11	30.65	27.30	26.91	27.74	25.97	23.07	20.07

Fig. 44: Thermal Comfort analysis of Naturally Ventilated Space



Day										
Air Temperature (°C)	26.73	27.87	33.12	31.25	31.37	31.29	28.39	28.42	28.51	27.04
Radiant Temperature (°C)	28.12	29.02	33.70	32.74	33.13	31.65	29.47	29.91	30.18	27.93
Operative Temperature (°C)	27.42	28.45	33.41	31.99	32.25	31.47	28.93	29.17	29.35	27.48
Outside Dry-Bulb Temperature (°C)	21.35	26.09	32.02	34.00	32.79	29.78	27.93	26.54	25.66	20.27

Fig. 45: Thermal Comfort analysis of Typical Floor

The average indoor thermal comfort was checked for a typical floor. Except in the month of April (during which the temp. exceeded by 1 deg. C), the thermal comfort temperatures were maintained for the rest of the year.

Ventilation, adaptive comfort- (*additional details are given in annexure sr. no*.10)

To enhance the ***natural ventilation***, the wind speed at sill levels of each floor is calculated as shown in table 02. The minimum wind speed at ground floor is 1.48 m/s and at seventh floor is 2.34 m/s. As per the reference of “Minimum wind speeds for just acceptable warm conditions” given in IS 3362:1977, it can inferred that the natural wind is within the range of acceptable wind speed for Raipur’s climate.

Table 11: Wind speed calculation

Floor mkd.	Sill ht. (m)	Wind speed (m/s)
Ground	1.50	1.48
First	5.10	1.80
Second	8.70	1.96
Third	12.30	2.07
Fourth	15.90	2.15
Fifth	19.50	2.23
Sixth	23.10	2.29
Seventh	26.70	2.34

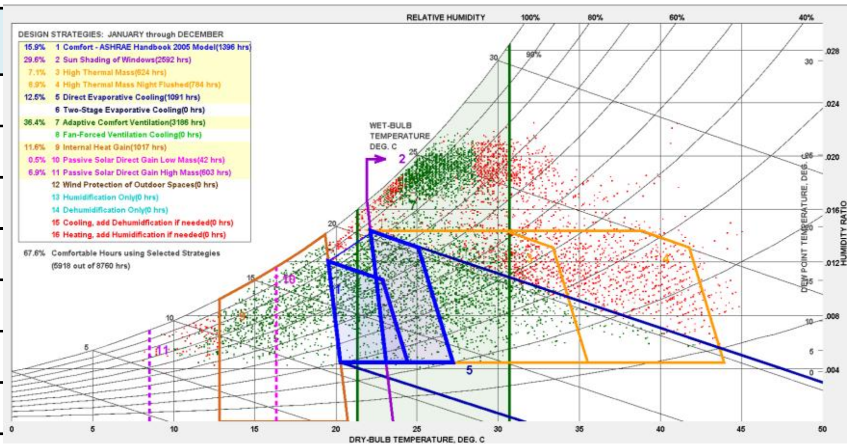


Fig. 46: Psychrometric chart (adaptive comfort model)

As per ***adaptive comfort model*** (ASHRAE 2005), it can be observed that the building can maintain thermal comfort for ***67.6% hours*** (5918 out of 8760 hrs.) annually with ***only passive design*** strategies such as shading, ventilation, night flush, heat gain, high thermal mass and evapotranspiration by landscaping.

iii. Provisions to enhance overall micro climate and other comfort parameters-

Landscape was envisioned at ***site level*** and the respective ***building levels*** to foster outdoor thermal comfort, user activity and rich biodiversity. So, the strategies are been developed to ***induce biophilia*** while facilitating ***enhanced IEQ*** with maximizing ***carbon sequestration*** and minimizing ***heat island effect*** while enhancing the ***ground water recharge*** *potential* with overall ***indoor air quality*** and ***adaptive comfort*** quotient.
As the east boundary of the site abuts the central 30 m road and the surrounding area is being developed as a commercial block, the traffic is expected to be ***heavy and consistent*** on all days. Therefore, the building block was ***shifted*** farther away from the boundary and a vegetation buffer was provided as a *noise blocking measure.* The glazing provided is ***triple layered*** for further ***noise reduction***.

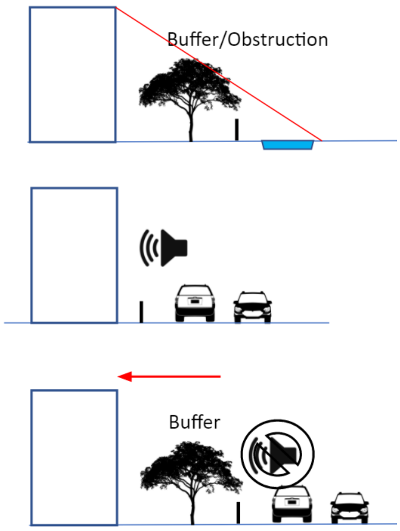


Fig. 47: Site level interventions

iv. Provisions to enhance Indoor air quality, health and wellbeing

Among the indoor pollutants*,* ***benzene*** found in petrochemical products, ***formaldehyde*** released from furnishing, insulation and wood based products, as well as ***trichloroethylene*** *(TCE)* found in cleaning products are the ***3 most harmful chemicals***. Therefore, use of ***low VOC*** paints, carpet tiles, sealant, adhesive, furniture etc. Also, when selecting the indoor plants, their ability to ***remove these pollutants*** is the taken into consideration.

For the plant selection, the ***air filtering plants list given by NASA*** during their clean air study was referenced and cross checked with the native plants list. 3 plants were selected based on this -

1. Gerbera Daisy – These plants grow well in warmer climates and are native to south-east asia. They are commonly proposed as they can remove ***38938 micrograms of TCE** and **107653 micrograms of Benzene** per plant*. Additionally they are flowering plants that add to the *aesthetics* of the space.

2. Bamboo Palm – Bamboo is a native tree species and abundantly found in Chhattisgarh. They are affordable and commonly used in households for air purification. These plants can remove ***16520 micrograms of TCE, 34073 micrograms of Benzene** and **76707 micrograms of Formaldehyde*** per plant.

3. *Sansevieria trifasciata* – Called as Dracaena trifasciata, or commonly referred to as snake plant. They are native to south Asia and very commonly used indoors. They are highly sought for aesthetics and high tolerance towards drought and heat. They can remove ***9727 micrograms of TCE, 28710 micrograms of Benzene*** and ***31294 micrograms of Formaldehyde** per plant.*


a.


b.


c.

Fig. 48: a) Gerbera Daisy; b) Bamboo Palm; c) Sansevieria trifasciata.

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