Solar™ Decathlon India

Final Design Report

April 2021

Team Navaritih
Office Building

Infosys
Mohali

Indian Institute of Technology Roorkee
National Institute of Technology Trichy

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3. EXECUTIVE SUMMARY

Our team Navaritih aims to design an office building for global consulting and IT services company Infosys limited at their Mohali campus. our main goal for this project is to design a net zero energy office building. We aspire to develop techniques to design energy and water efficient, affordable and resilient building with careful considerations to comfort, environmental quality and market potential. With innovative techniques we strive to design consciously and optimize the space design, façade system, and building management system.

Our goal was to design energy efficient building also to design a building which reduces Water usage through Recycling of water by reduce, reuse and recycling methods, promotes onsite Energy generation through Solar, Wind and Biomass Energy Sources, a resilient building which has the ability to reduce the magnitude and/or duration of disruptive events.

Energy is required in a large quantity for the building operations for the period of their whole lives. About 40 % of the total energy is consumed by buildings. Key issues in sustainability are depletion of resources and environmental pollution. It includes physical resources like fossil fuels, materials, and the human resources, at this point in time, if we still rely on these materials, we will have a big problem in future since we will no longer be able to extract enough material to meet the supply.

By using energy efficient techniques like efficient lighting design, optimized daylight, shading devices, optimized orientation and shape through simulations on various software's and considering all the design guidelines, we tried to provide a climate responsive and efficient design.

Special features of this building are windows having double glazed glass with low u value, Cavity walls with insulation, hollow concrete blocks, Sun exposed roof is insulated, use of efficient plumbing fixtures plus only recycled water is used for irrigation, lower flow rates in water taps and use of control systems, installation of sensors and use locally available materials.

4. TEAM INTRODUCTION

Team Name: Navaritih

Institutions Name

- Indian Institute of Technology Roorkee (Lead Institute)
- National Institute of Technology Tiruchirappalli

Division: Office building

Team Members

S.No	Name	Qualification	Role
1	Abhishek Palit	M.Arch 2nd Yr (IITR)	Team Leader, Energy Performance
2	Rajon Debnath	M.Arch 2nd Yr (IITR)	Architectural Design
3	Jagriti Kaushal	M.Arch 1st Yr (IITR)	Affordability
4	Urmi Sarkar	M.Arch 1st Yr (IITR)	Comfort and Environment Quality
5	Aditya Anand	M.Arch 1st Yr (IITR)	Water Performance
6	Shrutiksha Shrivastav	M.Arch 1st Yr (IITR)	Resilience
7	Sanjeev Krishnan R.	B.Arch 3rd Yr (IITR)	Innovation
8	Pranjal Agrawal	B.Arch 3rd Yr (IITR)	Resilience
9	Chanikya Kota	B.Tech 3rd Yr (IITR)	Engineering Design and Operation
10	Ashish Anand	B.Tech 4th Yr (IITR)	Scalability and Market Potential
11	Priya Patel	M.Arch 1st Yr (NITT)	Architectural Design

Table 1: Team Summary

Approach

Workflow in the team:

We have divided our team according to the 10 contests provided in the design brief, each team member was provided with a contest according to their area of interest. All team members are free to give their suggestions for the whole design process but their prime focus will be on the contest selected by them .Each contest has a individual lead and the team is led by 2 team leaders who will manage the whole team and motivate all the team members to achieve goals and develop the required skill set to get results.

Process:

After deciding our goals to design a Net zero energy water building, the process starts with site potential analysis, location, orientation, climate analysis and consideration of other parameters which are required to enhance the building design. We will incorporate energy use, water consumption, comfort, affordability, resilience, technical aspects and all the contests given to us as challenges in design. By incorporating some of the design features like prefabricated walls, solar passive design elements, radiant heating system, usage of vernacular materials, rainwater harvesting system we aspire to achieve our goals.

Faculty Lead: Dr. Prabhjot Singh Chani

5. PROJECT BACKGROUND

a. Project Name: Infosys, Mohali

b. Project Partner:

   a. Name of Organization: Infosys Limited
   b. Background: Infosys Limited, is a NYSE listed global consulting and IT services company in India, with more than 239k employees that provide global leadership in digital services, business consulting and outsourcing services. Established in 1981, by seven engineers in Pune, Maharashtra, India. It has nine development centers in India and over 50 offices worldwide. In their journey of 39 years, they have catalyzed some of the major changes which led to India's emergence as the global destination for software services talent. Infosys pioneered the Global Delivery Model and became the first IT Company from India to be listed on NASDAQ. Their employee stock options program created some of India's first salaried millionaires. (Reference: https://www.infosys.com/about/history.html)
   c. Name and designation of key individuals involved: Guruprakash Sastry, Regional Head – Infrastructure, Infosys Limited

c. Brief discussion of Project:

   - Location: Mohali, Phase- 1, Punjab
   - Stage of the project: Design Stage
   - Purpose: Build-Own-Operate
   - Estimated total built up area: 18,605sq.m

d. Special requirements of the Project Partner:

   - Building Adheres to NBC 2016 Part 4 Fire and Safety Norms.
   - Sewage to be treated 100% at site with zero discharge.
   - Building Area Program: Modular planning, Flexible, Scalable, Defined circulation, Easy accessibility for pantry and space efficiency should be 90sft / person.
   - Energy requirements:
     - EPI < 70 kWh/m2/year
     - LPD: 0.5 W/Sq ft
     - HVAC: 750 Sq ft/TR
     - Electrical: 3.5 W/Sq ft

e. Context and Market Analysis

The site is in Mohali (SAS Nagar) (SAS Nagar) Phase 1, Punjab. Mohali town was initially conceived as an Industrial town after reorganization of Punjab in 1966. Today, Chandigarh and SAS Nagar are joined with only the boundary of Punjab and Chandigarh UT separating the two from each other. The original plan of Mohali town is an extension of architectural pattern of Chandigarh.

Infosys focuses on large enterprises who have IT budget and needs. Infosys is an India multinational corporation that provides business consulting, information technology and outsourcing services. Infosys has 82 sales and marketing offices and 123 development centers across the world as of 31 March 2018, with major presence in India, United States, China, Australia, Japan, Middle East, and Europe.

6. PERFORMANCE SPECIFICATIONS

- <u>Climate Zone</u> - Humid Subtropical Climate

- <u>Performance specifications:</u>

i. Envelope

Window Assembly – Double glazed (SunGard® extra Selective SNX 50) window with U-Value of 1 W/m²k and low SHGC value 0.28 and VLT of 49.6%. Composition 6mm / 16 mm / 4 mm with Gap 1 10% Air, 90% Argon.

External Wall – We used a wall assembly which contains layers of Autoclaved Aerated Concrete (AAC) Blocks, interior and exterior plaster with XPS insulation of 79.50mm thickness with 100mm brick cladding. Wall U-Value - 0.350 W/m²k

Roof Assembly – Reinforced cement concrete with plaster on both sides as double skin roof with insulation of glass wool is provided with 10mm asphalt coating. Roof U-Value - 0.250 W/m²k

ii. HVAC System

System Type – Radiant Cooling – Thermally Activated Building System (TABS) coupled with Dedicated outdoor air system (DOAS). Energy Benchmark – 750 Sqft/TR
COP – 3.6

iii. Lighting (LPD) – 0.5 W/sqft

iv. Electrical (EPD) – 3.5 W/sqft

v. Renewable energy
System Type – Fixed (Open Rack)
Generation Capacity - 391828.15 kWh

vi. Water systems

Consumption reduction strategies

- Waterless urinals
- Efficient aerated faucets
- Efficient
- Use of municipal water and balance that consumption with ground water recharge.

For controlling the groundwater recharge a water body is introduced which provides enough time for soaking up that amount of water and also control and store the water to be used in unfavorable conditions.

Another system is introduced to break the speed of stormwater to settle down the dust and other suspended particles to the sedimentation chambers attached just after the speed breakers.

7. GOALS

i. **Energy performance**

Target Energy Use Intensity of less than 70 kWh/m2/year.
Spatial daylight autonomy 300/50% of at least 50% of regularly occupied area.
Lighting Power Density of 0.5 W/Sq.ft, HVAC Load of 750 Sq.ft/TR
Electrical load of 3.5 W/Sq.ft

ii. **Water Performance**

Reduction of Water usage through Recycling of water through reduce, reuse and recycling.
Average per capita consumption by NBC standard is 45ltr per head/day.
By use of efficient fixtures, it can be achieved to 40ltr per head/day.
Total consumption per head/day for 1500 capacity will be- 60000ltr per capita/day.
Goal to achieve - 70% reduction in freshwater consumption.

iii. **Resilience**

Power back up during calamities & Design Measures for Risk Management and disruptions.
Resilience to Earthquakes, Heat Waves & Flooding, Structure design as per the guidelines

iv. **Affordability**

To reduce the cost of construction and carbon emission by using locally available materials.
Use of appropriate construction system to reduce the cost and on-site waste.
Right sizing of the HVAC systems for energy efficiency.

v. **Innovation**

Our goal is to innovate a sensor less Building Automation System (BAS), so that the installation, operation, and maintenance cost get reduced to almost zero which in turn would encourage a lot of people to implement BAS in their buildings. This saves a lot of energy.

vi. **Scalability and Market Potential:**

The goal is to propose an office building design model that can be reproduced in different part of the country capable of tackling the environmental challenges and is cost and time efficient

vii. **Comfort and environmental quality**

Our goal is to provide good Indoor air quality and thermal comfort through the use of passive design strategies, Minimum Active Technology, No direct solar radiation on any workstation, more alert employees, better energy level, better productivity and health.

viii. **Architectural design**

Our main goal for design is to achieve net-zero energy water building through use of passive design techniques, efficient technologies, renewable energy resources, energy conscious design, low embodied energy using materials, Construction, and operations of the project.

ix. **Engineering design and Operation**

Design of Exterior Façade and Interior walls with prefabricated drywall construction. Incorporation of Building Information Modelling for increased accuracy of cons

8. DOCUMENTATION OF DESIGN PROCESS

The design team included six members of the team. (Rajon, Priya, Abhishek, Urmi, Jagriti and Pranjal). The initial discussion included the identification of major spaces required in the building. We used Miro App to collaborate on ideation of design.

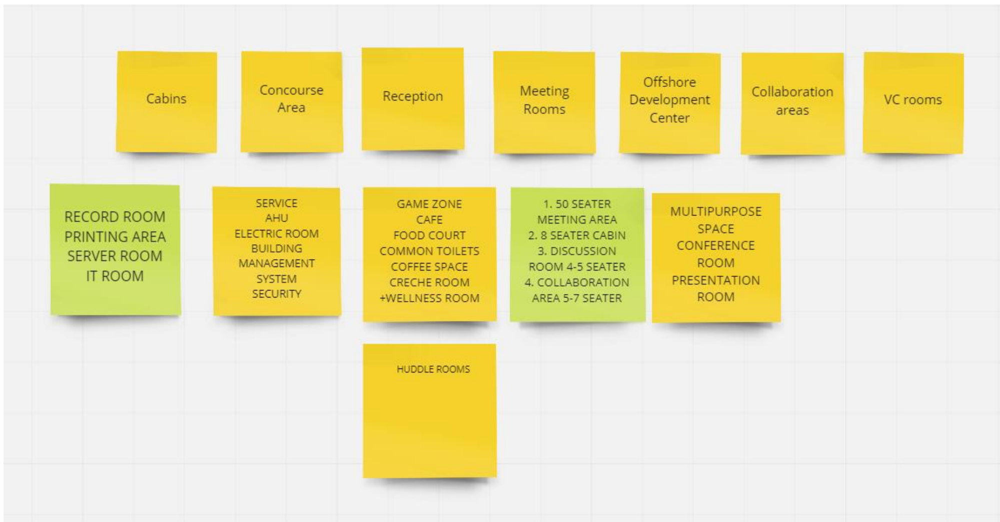


Figure 1: Space Requirements

After we had finalized the spaces, the team started to identify proximity of spaces using the Miro App. Each floor layout with proximity was identified.

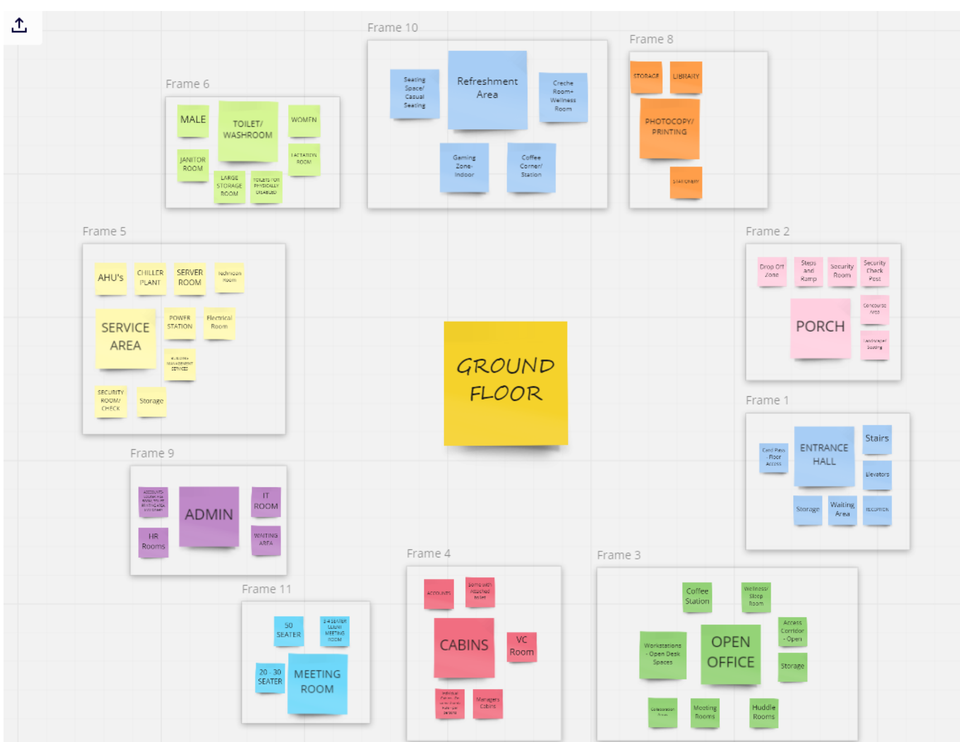


Figure 2: Proximity Map

Next, we had discussion with the Project Partner from where we finalized the Area requirements for each space typology and finalized the space requirements.

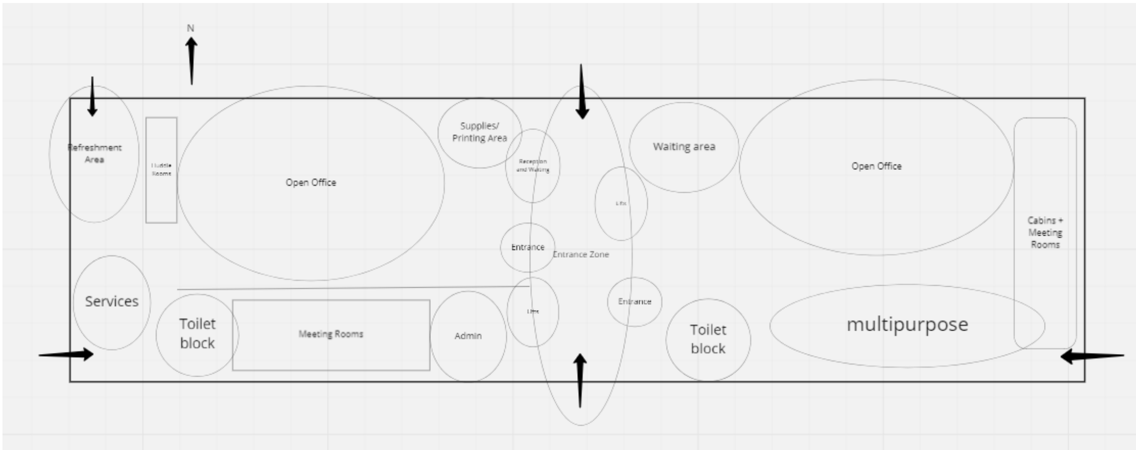


Figure 3: Bubble Diagram

After the space requirements finalized., the team identified the optimum form of the building and then finalized the Plan layouts of the building.

Figure 4: North Facade

Figure 5: South Facade

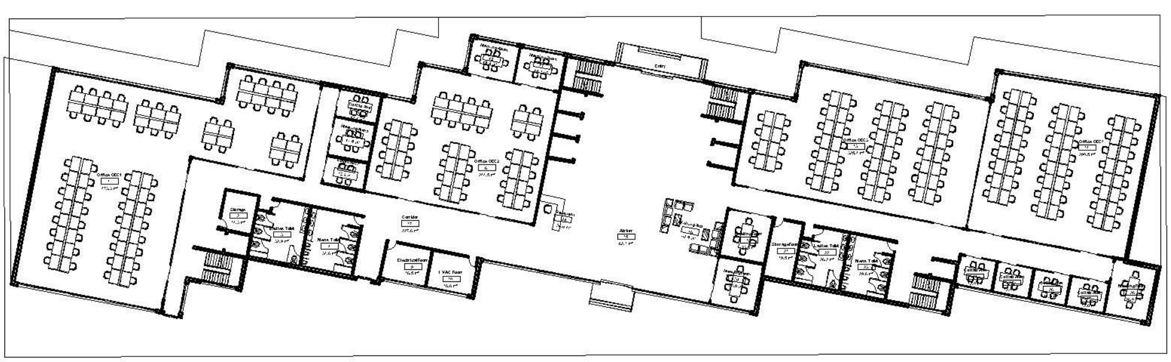


Figure 6: Final Plan Layout (Ground Floor)

9. DESIGN DOCUMENTATION

A. ENERGY PERFORMANCE

On-site Renewable Energy Generation Potential:

i. Solar energy

Area Covered for PV Panel	4495 sqm
Module Type:	Standard
Array Type:	Fixed (open rack)
Array Tilt (deg):	32
Array Azimuth (deg):	4
System Losses:	11.42
Invert Efficiency:	96
DC to AC Size Ratio:	1.2
Total PV Output	391828.15 kWh

Month	AC System PV Output(kWh)
January	13933.43
February	17999.69
March	34872.81
April	45406.02
May	56357.86
June	49859.38
July	47207.59
August	42172.46
September	34709.93
October	24185.15
November	14056.55
December	11067.28
Total	**391828.15**

Table 2: Monthly PV Output

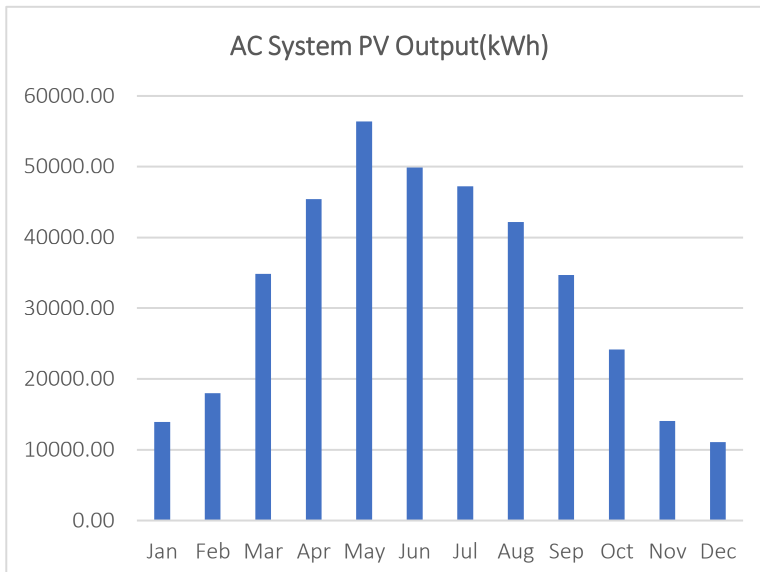


Figure 7: Monthly PV System Output Graph

ii. Wind energy

Generation = rating*capacity factor*hours
= 1KW x 16x 3600(5 MONTHS)
=57600kwh

iii. Biomass power generation

Estimated biomass = 0.67 ton/day
A 5kw power plant can be fed.

Total On-Site Energy Generation = 391828.15 + 57600 kWh = 449,428 kWh annually.

Building Energy Consumption

	District Cooling [Kwh]	Lighting [Kwh]	Equipment Electricity [Kwh]
January	49471.08	1518.72	10190.82
February	61225.8	1067.4	8904.18
March	144046.2	951.36	9414.72
April	166044.72	781.08	9761.94
May	202239.78	630.24	10190.82
June	179302.86	619.02	8985.9
July	161595.9	659.58	10190.82
August	139947.24	766.2	9802.8
September	147169.68	917.22	9373.92
October	124753.5	1266	10190.82
November	69195.24	1315.62	9373.92
December	47356.74	1452.18	9802.8
Annual Sum	1492348.74	11944.62	116183.46
Total Electricity Demand	1620476.82		
Total Building Area	18605 sqm		
Achieved EUI	87.10		

Table 3: Building Monthly Electricity Consumption

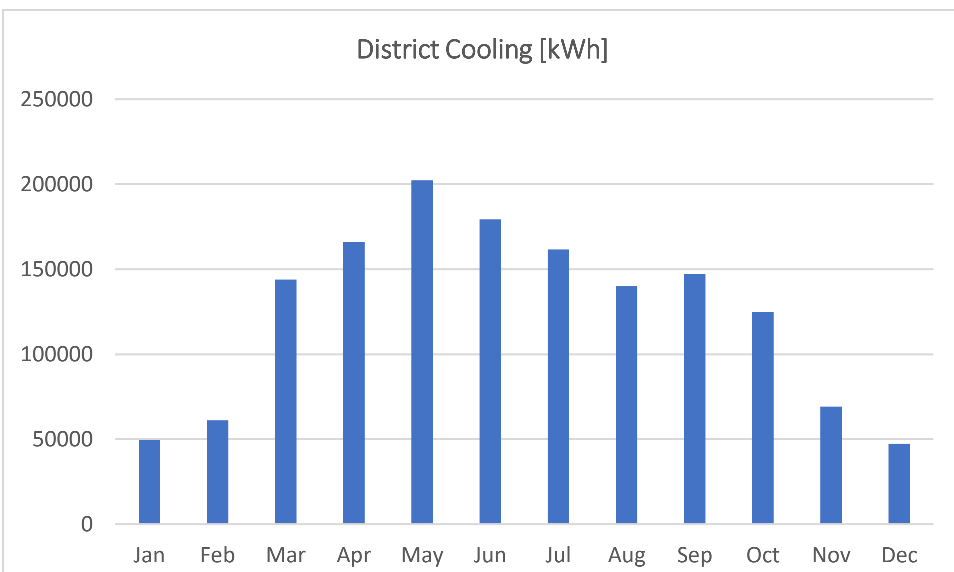


Figure 8: Cooling Electricity Consumption

Measures to minimize Energy Demand

i. Daylighting – To Minimize Lighting Load

The Building has 46% of Areas with sDA 300/50.

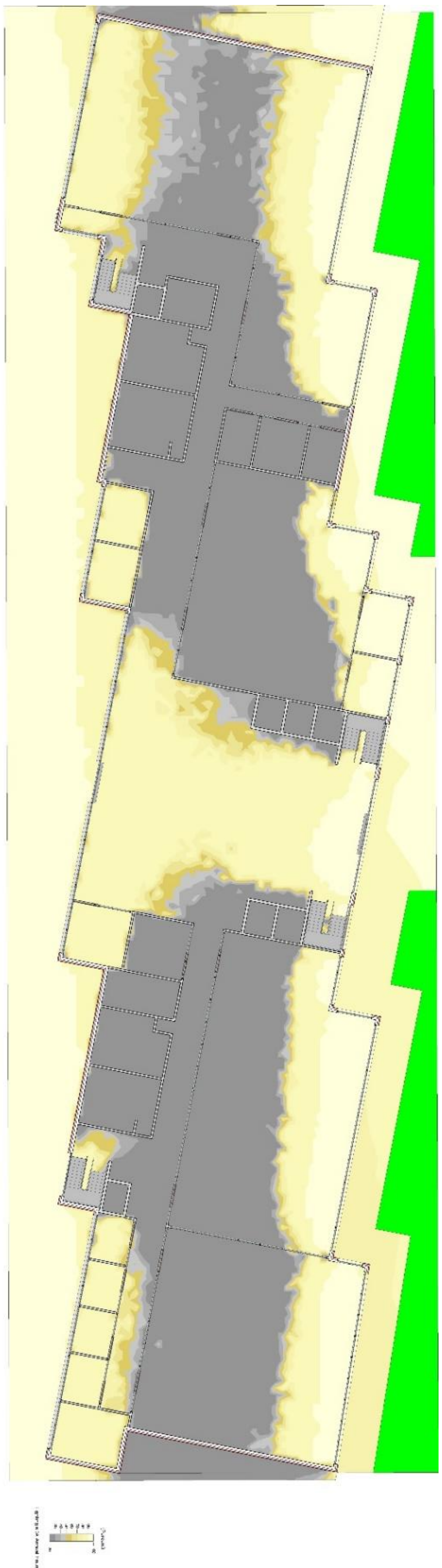
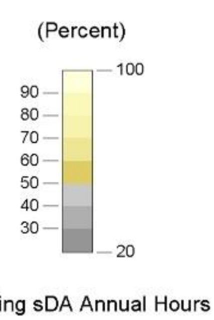


Figure 9: Ground Floor Daylight Simulation

Space Name	Number	Area	sDA 300/50
			%
Office ODC 1	1	473.3 m^2	59
Collab Area	5	12.7 m^2	0
Meeting Room	6	17.6 m^2	0
Collab Area	7	12.4 m^2	0
Office ODC 2	8	244.5 m^2	18
Electrical Room	9	18.5 m^2	100
HVAC Room	10	18.8 m^2	100
Meeting Room	11	18.2 m^2	100
Meeting Room	12	18.8 m^2	100
Office ODC 3	13	325.4 m^2	41
Office ODC 4	14	290.5 m^2	31
Atrium	15	82.1 m^2	100
Waiting Area	16	61.5 m^2	88
Corridor	17	227.8 m^2	14
Reception	18	20.5 m^2	59
Meeting Room	19	23.5 m^2	0
Meeting Room	20	24.0 m^2	100
Collab Area	24	12.0 m^2	100
Collab Area	25	12.0 m^2	100
Collab Area	26	11.9 m^2	100
Collab Area	27	12.6 m^2	100
Meeting Room	28	26.0 m^2	100
Corridor	29	147.1 m^2	28
Entrance Lobby	30	260.8 m^2	86

Table 4: Spatial Daylight Autonomy



ii. Building Façade – To minimize Heat Gain

Through Radiation analysis we got to know that south, east and west façade are receiving maximum solar radiation so we needed to cut down solar radiation in these facades. West façade does not have openings. AAC blocks are used for wall construction with XPS insulation of 79.55 mm to protect the walls from sun and avoid the heat gain. Windows are provided with double glazing and u value of 1 w/m²k and low SHGC value 0.28 and VLT of 49.6% and roof has the been provided with RCC and has a double skin façade with glass wool insulation which reduces the u values up to 0.25 w/ m²k.

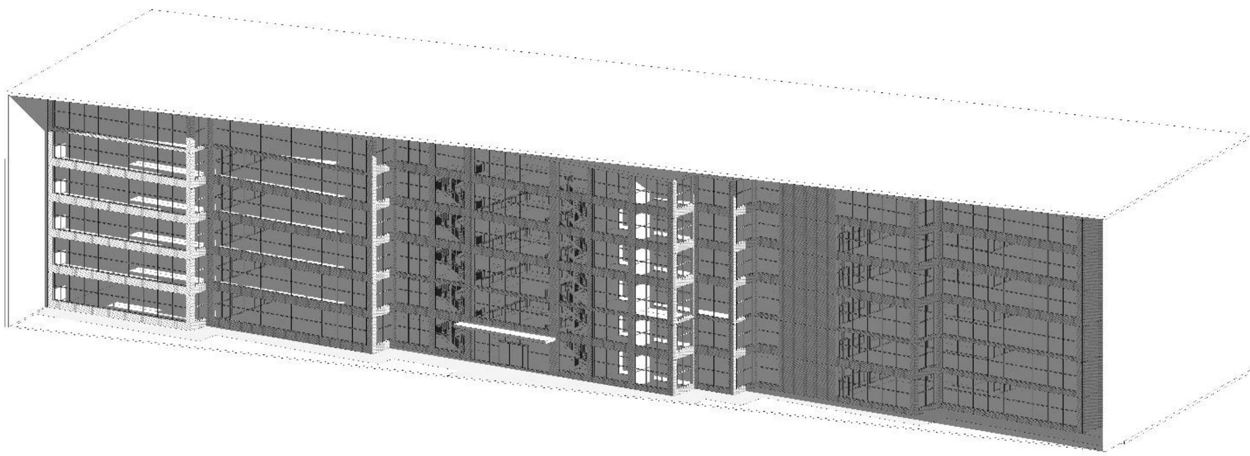


Figure 10: North Facade

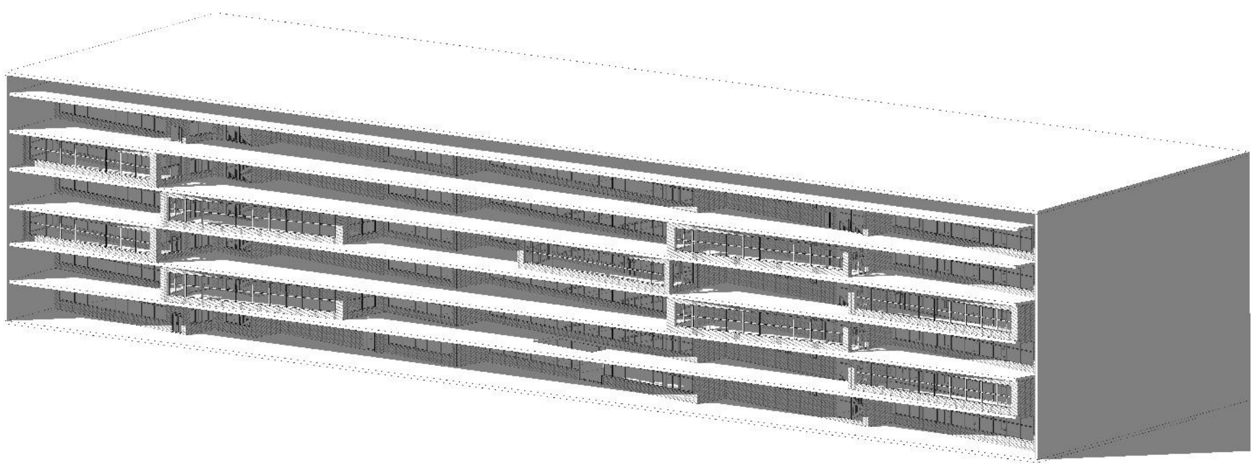


Figure 11: South Façade

B. WATER PERFORMANCE

S.no	Goals to achieve	Goals achieved	Remarks
1.	40ltr Per capita freshwater consumption	39ltr Per capita freshwater consumption	For per capita freshwater requirement, the clients demand taken into consideration and provisions are made to return that much of amount to ground to make it a net zero water building.
2.	Use of recycled water wherever possible	Recycled water is used in landscaping, HVAC, and toilet flushing.	Use of recycled water is decreased with the use of waterless urinals as major part of this was being used for flushing.
3.	Efficient storage	4-day storage of municipal water is provided.	Instead of spending on Storage of rainwater in large amount in tanks, municipal supply with 4-day storage is used. For the rainwater storage a water body is made to store the rainwater and helps to provide it enough time to be soaked up inside for ground recharge through nearby soak pits.
4.	100% on-site sewage treatment with zero discharge	100% sewage is treated on site	STP plant on site is used to treat the generated sewage.
5.	Net-Zero water design	Net-positive water design is achieved.	With ground water recharge (rainwater + recycled water), the amount of water used in the building is balanced with the amount of water sent back for groundwater recharge.

Table 5: Water Performance Goals Summary

i. Water flow diagram.

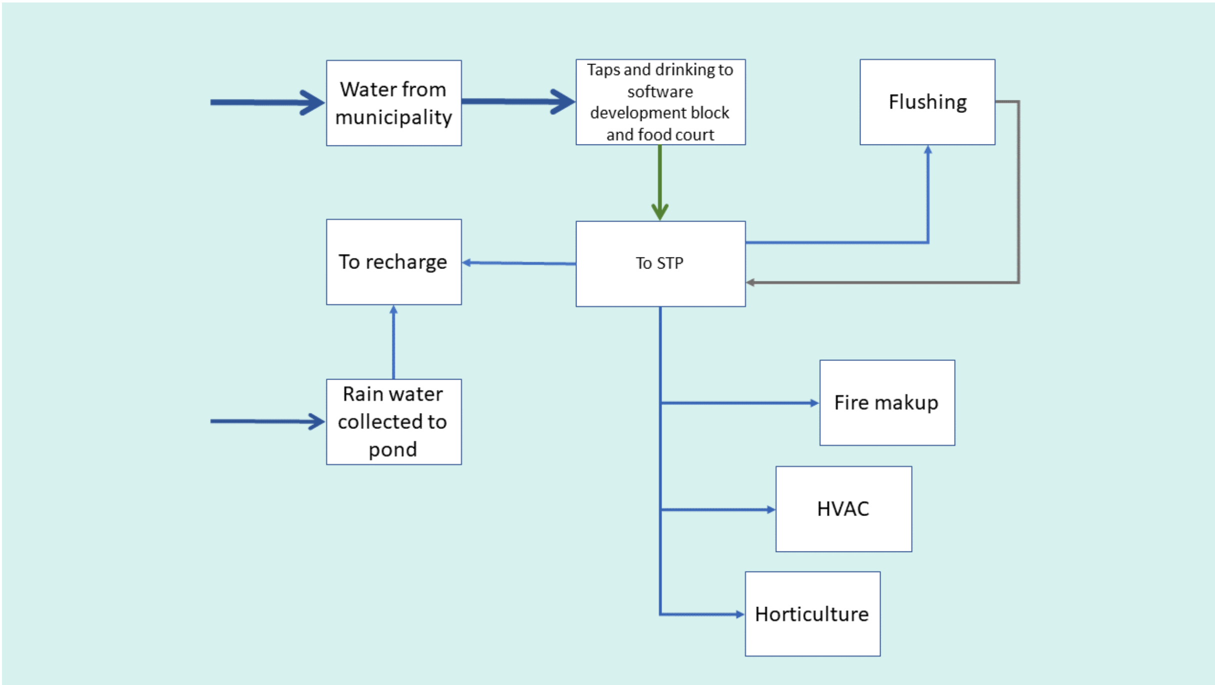


Figure 12: Water Flow Diagram

ii. Net-Positive water loop diagram.

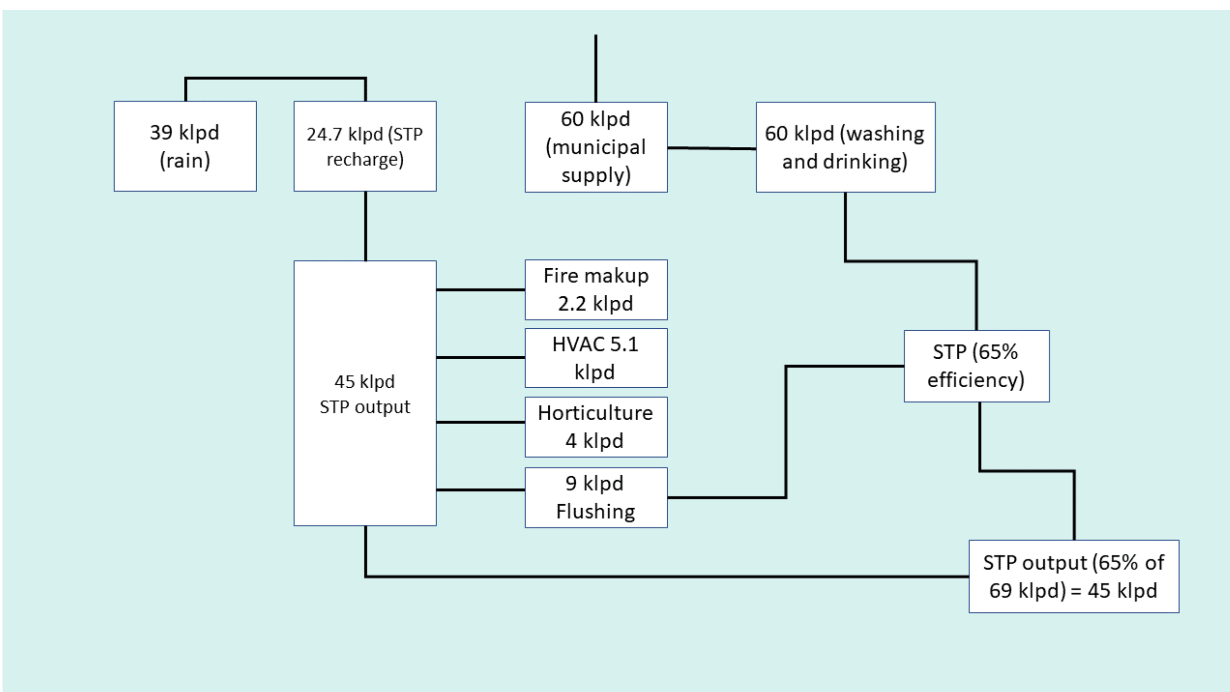


Figure 13: Positive water loop diagram

iii. Water collection area break-up.

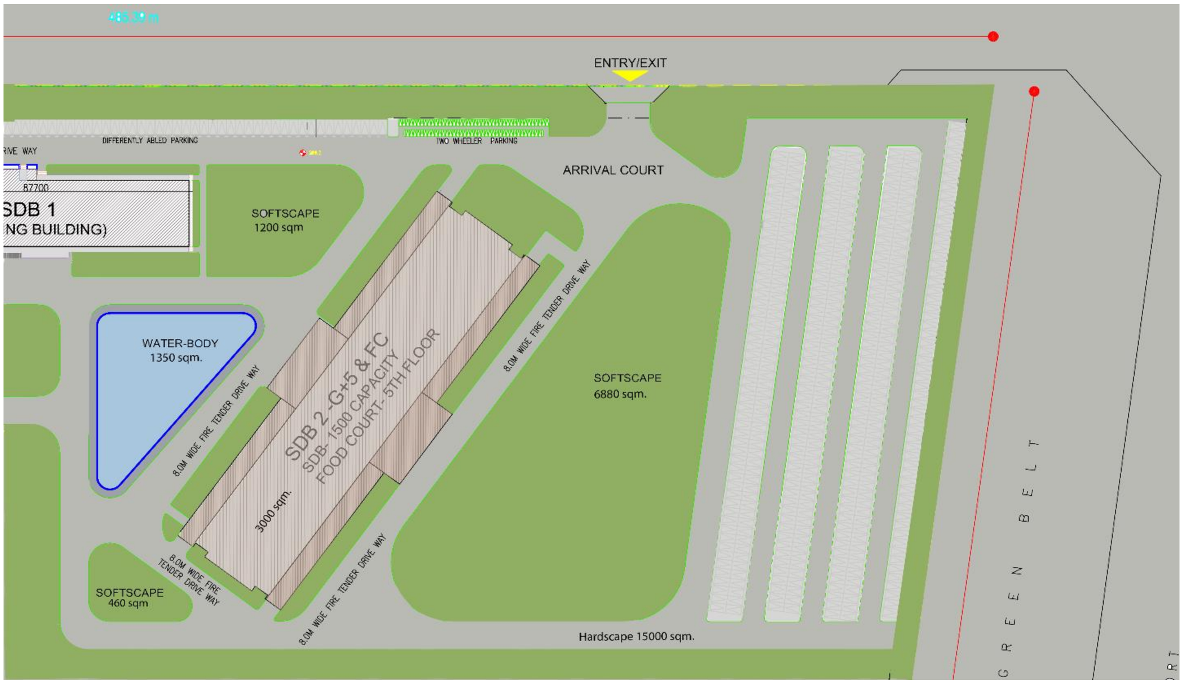


Figure 14: Water Collection Area-breakup

iv. On-Site integration

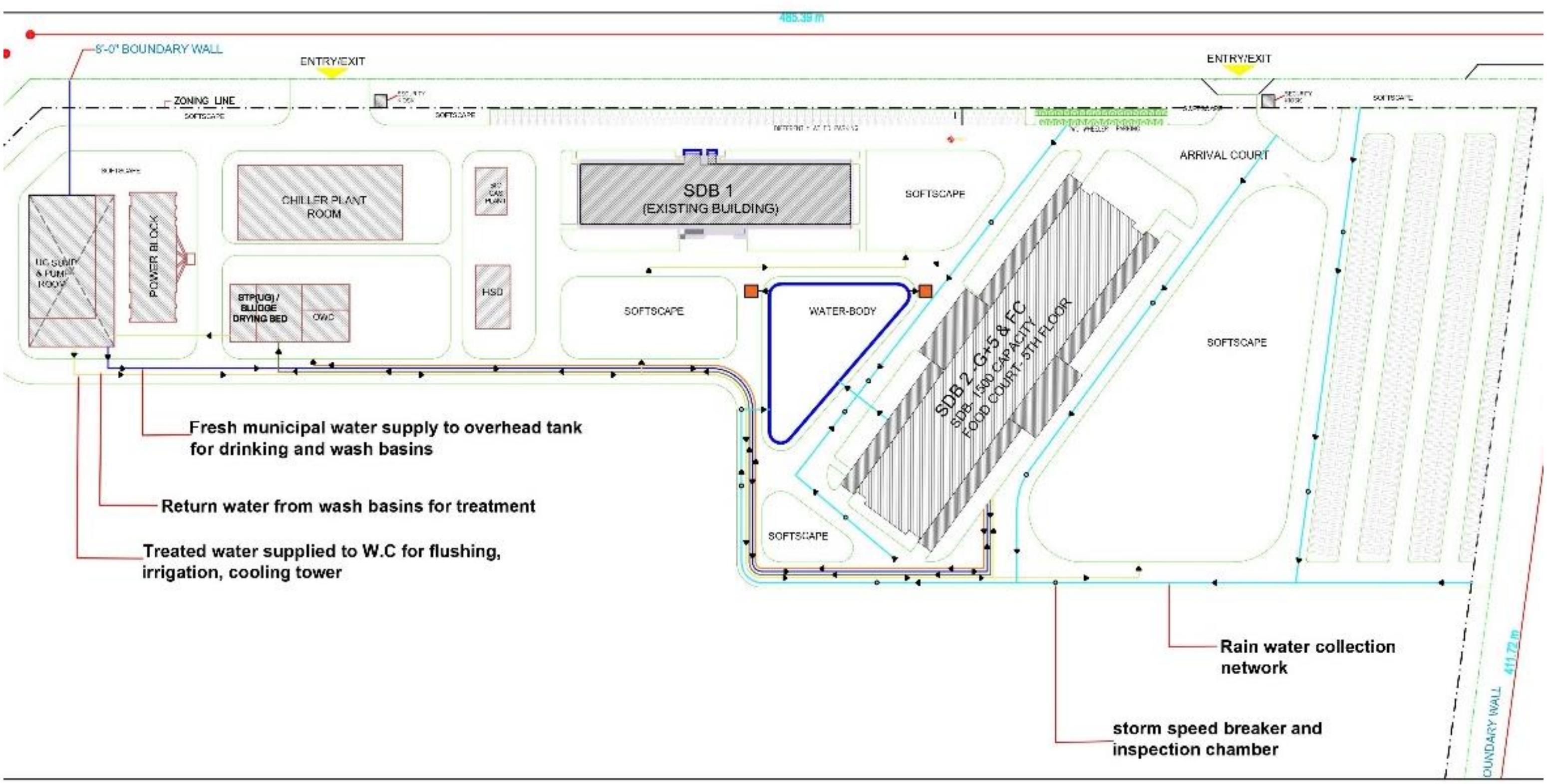


Figure 15: On-site water loop integration diagram

v. **Water body-controlled ground water recharge.**

A water body on site is used to control the ground water recharge. Two recharge pits with depth of 25 feet are used in opposite directions to be used for ground water recharge, water goes into the pits through automated controlled inlets provided at 6 feet from bottom of water body. The water body rises further 5 feet above the inlet.

The dimensions and opening height are provided on basis of calculations of rainwater collection and recycled water quantity.

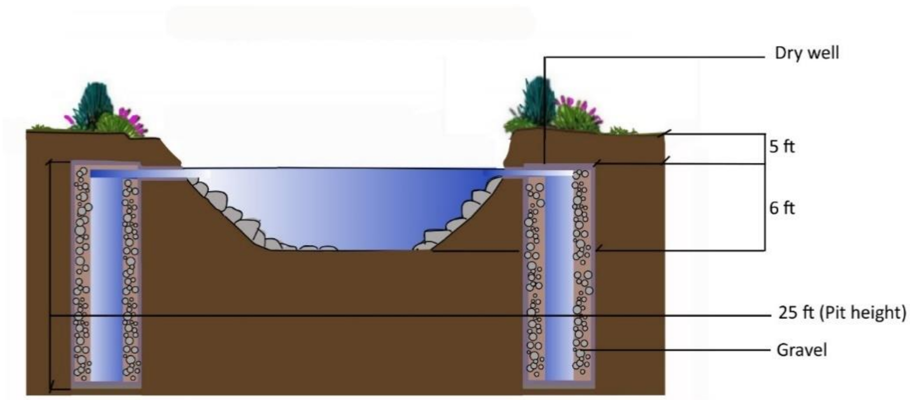


Figure 16: Waterbody integrated recharge pit.

vi. **Sedimentation chambers and storm water speed reduction.**

Rainwater collected from places goes to the water body, the impurities are reduced by passing it through sedimentation chambers. Before entering the sedimentation chamber, the speed of this water is reduced by 360-degree rotation of the flow.

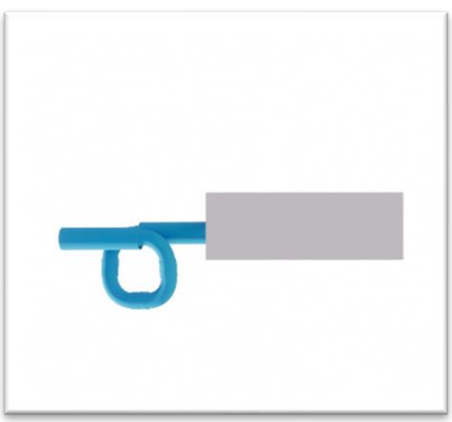


Figure 17: 360-degree movement of flow for breaking storm-speed and sedimentation chamber

vii. Toilet layout

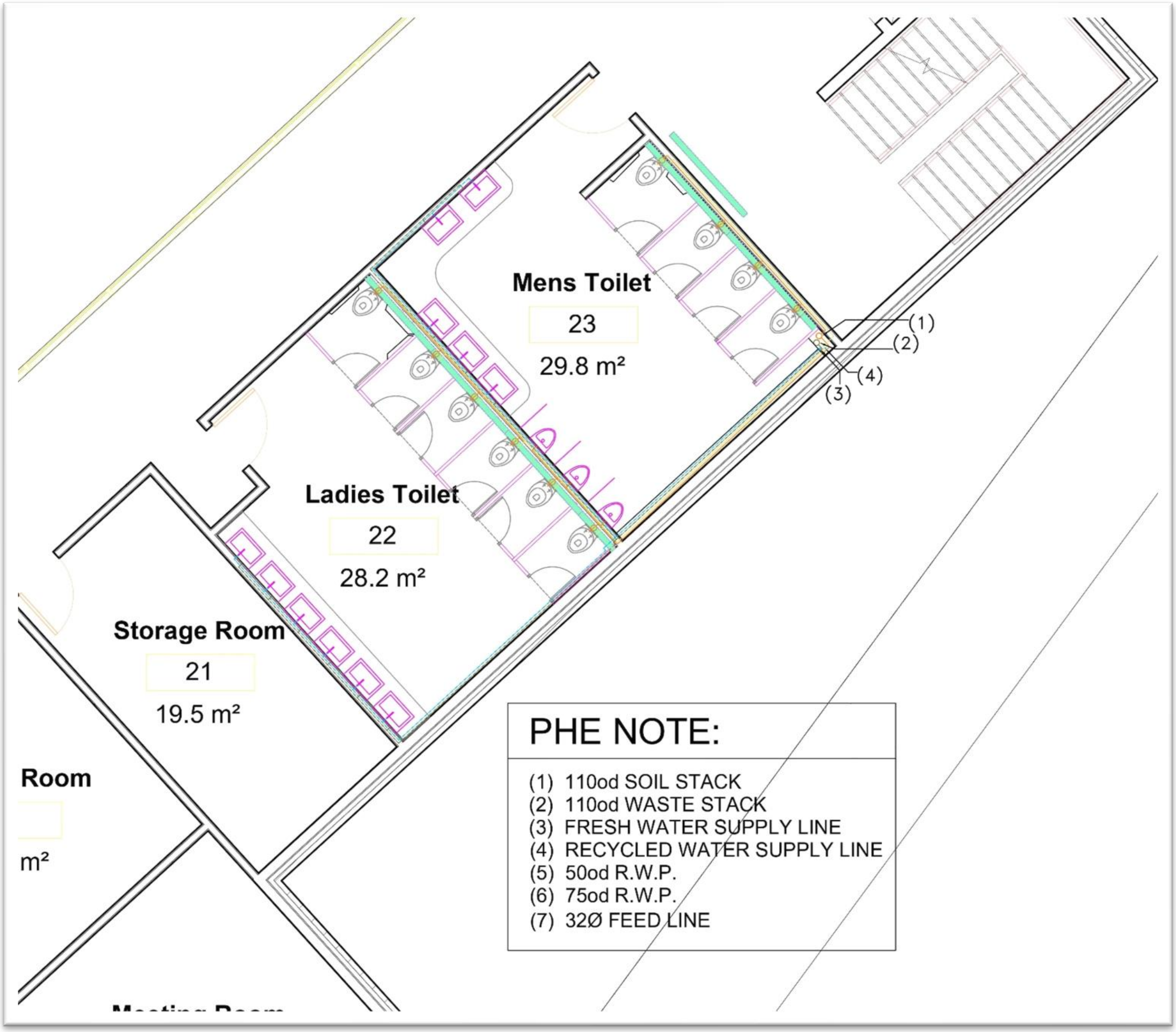


Figure 18: Toilet layout

C. RESILIENCE

i. Pandemic Resilience Strategies

- Complete sanitization on entry points.
- Screens to separate working area in open office
- Air sanitization devices in the open offices
- Reducing the number of processes that includes physical contact
- Maintaining social distancing in public spaces
- Providing strategies to transfer to complete work from home mode in case of future such pandemic disasters with more focus on areas for virtual interaction.

ii. Power back up during calamities & Design Measures for Risk Management and disruptions.

· Power back up during calamities & Design Measures for Risk Management and disruptions. Rooftop Photo-Voltaic (PV) systems have the potential to supply electricity during grid disruptions resulting from extreme weather or other emergency situations. When in place, the Electricity System Resiliency will limit the consequences of a power disruption and specifically address protection of life and property.

iii. Resilience to Earthquakes, Heat Waves & Flooding

· Our site lies in seismic zone 4

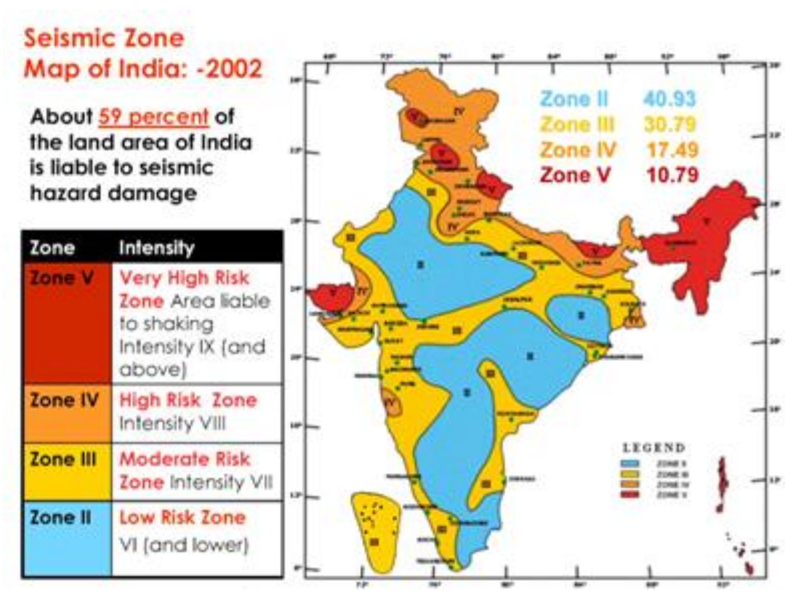


Figure 19: Seismic Zonation and Intensity Map of India

Structure design as per the guidelines mentioned in

- IS 4326 (1993) - EARTHQUAKE RESISTANT DESIGN AND CONSTRUCTION OF BUILDINGS — CODE OF PRACTICE
- IS 1893 (1984) - CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES

With temperature reaching 42 degrees in summers ad frequent heat waves in the region mitigation strategies like shaded rooftop areas, a more thermally resistant building envelope, and the standard provision of air-conditioned office areas provide resiliency against heat waves. The orientation of the building is based on the data of annual Solar Heat Gain Radiation and wind flow to keep the temperature of the building in comfort range. Data mentioned under energy performance head.

The project partner already had a well-developed campus in terms of security and resilient strategies in terms of water storage at times of drought and fire were developed earlier in view of further developments. Water storage for 2 days from the in-situ storage facility and 5 days from the nearby natural reservoir. Further data mentioned under water performance head.

As per the requirement of the client for resilience in terms of cyber security, the server rooms are placed to ensure security both from physical attacks and cyber-attacks, our team is still working on how we can ensure the same in the final project.

An idea for a closed mobile application for the employees which will have an early warning system for natural disasters and a quick alarm system in case of fire in any part of the building. Employees can also use the application for sharing data and files within an ODC so that the cyber privacy is maintained.

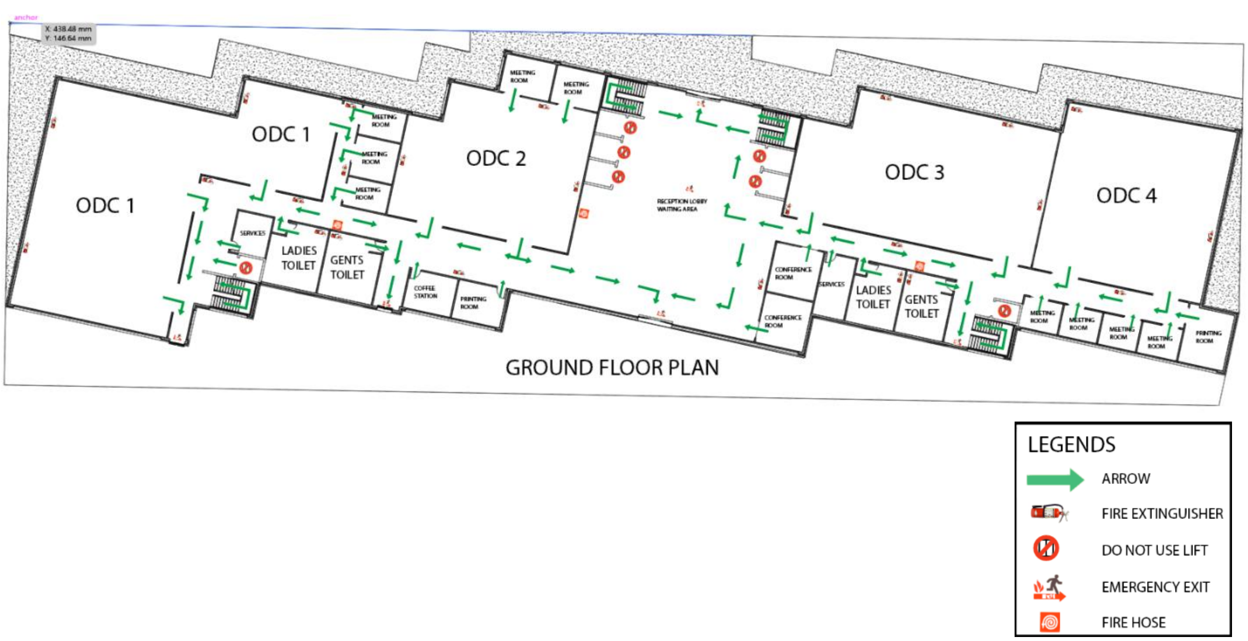
The site is situated far from low-lying flood plain of Mohali. Strategies are incorporated for water collection at the time of heavy rain. Since the project is extension on the pre-developed site recovery strategies at the time of natural disaster were already taken care off by the project partner.

iv. Resilience To Fire

The Infosys office comes under business building therefore it lies in fire zone 2 of the city. IS.1641.1988 guidelines are incorporated in the building.

Below is the evacuation plan and fire zones description of the proposed office building.

Fire Evacuation Plan



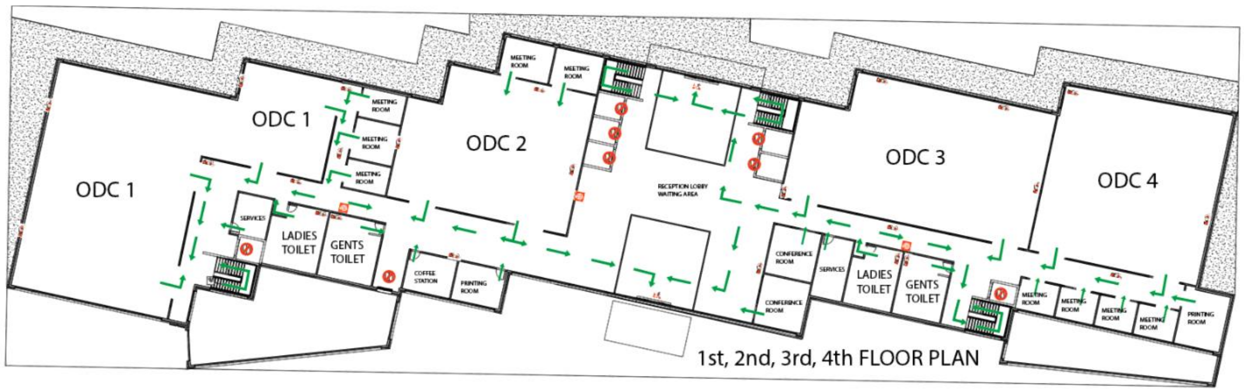


Figure 20: Fire Evacuation Plan

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Fire Zoning

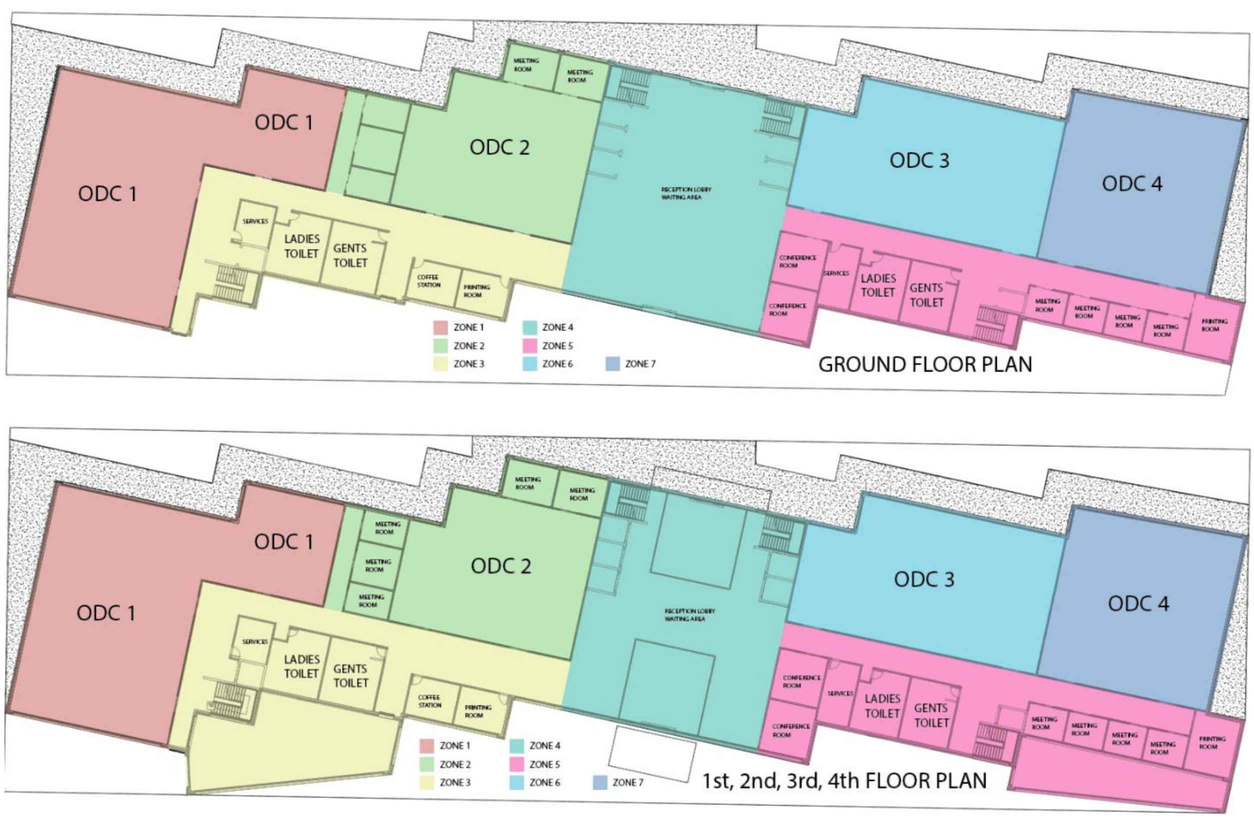
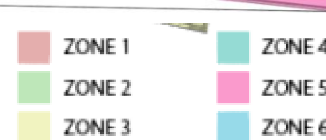


Figure 21: Building Fire Zoning



D. AFFORDABILITY

Design strategies for Rightsizing and Optimization

- **HVAC system**

Thermally Activated Building System (TABS) is used for the radiant heating and cooling of the building. As the tubing used in the system is embedded in the floor slabs, the size of the visible components like ducts and AHU's can be reduced, resulting in reduced floor to floor building heights. The embedded tubing system requires no maintenance including the chilled water source and distribution. The DOAS system used by the radiant cooling system not only reduce the operation costs but make a significant difference in the capital costs.

- **Water performance**

To improve the water consumption, Faucet Aerator with sensor is used in the faucets. It is water efficient and low maintenance.

For harvesting rainwater, a water body is used on the site instead of constructing a large tank.

- **Structure system**

A flat slab system is used in the structure system, which gives flexibility in the design layout. It will reduce the floor-to-floor height resulting in reduced building height and foundation load. It takes less time in construction and M & E services can be easily installed on it.

- **BIM 5D sequencing**

In conventional estimating techniques, where we use 2D drawings there will be a chance of inefficiency and error, but a three-dimensional project model removes the ambiguity and potential inconsistencies in project quantity estimations.

In BIM we can automatically generate the quantities from the model itself. Provides cost loaded schedules and the data can be queried at any time during a project and the information that feeds cost reports is regularly updated.

Design strategies for economy and cost of finance in construction

- **Materials**

The materials used in the facade system are used on the preference of their availability in the local market. This will reduce the embodied carbon and make the process more sustainable.

AAC blocks used for walls will reduce the construction time due to their size and thus construction cost will also be reduced.

- **Finance**

The project is fully financed by the client itself, Infosys Limited.

E. INNOVATION

Problem Definition

In maintaining the energy efficiency of the building, building automation plays an important role. With the rise of modern technologies and inventions in the field of building automation, the energy-saving capacity of buildings has exponentially risen. In fact, sensors, actuators, and controllers, which collectively serve as the backbone of cyber physical systems for building energy management, are one of the core technical areas of investment for achieving the goals for energy affordability being mentioned by various standards. But, at the same time, installation and maintenance of these sensors, actuators and controllers is not an easy task. Starting from selecting the appropriate sensors, designing the network, installation, testing to regular maintenance of these networks needs a lot of effort and resources. A lot of money and human resource is being deployed at this section to achieve that exponential level of energy saving. Even after spending a lot of resources on this, it is highly prone to hardware errors and even a small error can halt the whole automation system of the building which in turn would increase the energy consumption and operational cost. Especially in office buildings, where building automation is done on a large scale, it has a very big impact. To solve this issue, a lot of resources are being done to increase the efficiency of the sensor, actuator and controller network itself, like wireless sensors, smart sensors etc. But still, a remarkable solution is not yet achieved. We seek to address this problem by proposing a sensor less building automation system.

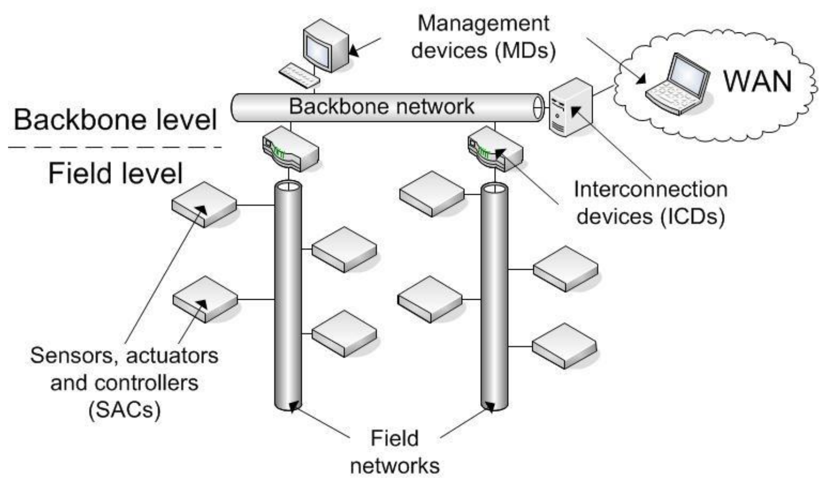


Figure 22: Typical Architecture of BAS

Proposed Solution

We have designed an IT office building. The core job being carried out here is through computers and computer network. Every individual has a LAN port near to his table and his computer, in which he works for almost 85% of his total presence time within that building. All these computers are connected to the local server and the total data transfer happens through it. We primarily aim to estimate the current occupancy of an area by analysing the traffic of data in that particular area and hence operate necessary systems accordingly. With this, we can sense the occupancy and control the lighting and other electric fixtures accordingly. When it comes to sensing the thermal comfort of the occupants, we aim to develop an AI model which will be deployed at the server. This model will analyse the data being transferred from/to an individual's computer and predicts his thermal comfort. We expect this model to produce results at high accuracy because the output of any person is strongly related to his thermal comfort. Other factors related to the output of an individual will not affect the accuracy of our model because we plan to train our model with a vast dataset from various office types, various regions, various age groups, various shift schedules, various time frames etc. By predicting thermal comfort, HVAC systems can be operated efficiently. By estimating the occupancy and predicting the thermal comfort just through the data traffic, we aim to totally remove all kind of sensors present in primary functional spaces like office spaces, meeting rooms etc., except water management sensors. For rest of the spaces like cafeteria, toilets, lounges etc., the occupancy will be predicted using AI model by taking inputs like the total current occupancy of the building (from the electronic attendance record), current occupancy of office spaces, and other relevant data. Our secondary aim is to deploy an RL (Reinforced Learning) model which can continuously take inputs from the users to increase the accuracy of the results produced. On the other side, we will use wireless, internet-connected fixtures, actuators and controllers where each element will have its own address in the network. By this, it is very easy to operate these components, installation and maintenance cost is less, and if any error is spotted it is very easy to locate it and fix it without affecting the rest of the system.

Target Market

Our primary target is office buildings where computer network forms the core of the office functioning. As we are only dependent on core hardware of such offices and no other extra hardware are required, it is very easy to implement our solution in their offices. Not only in 'under-construction' or 'to-be-constructed' buildings, even in functioning offices, it is easy to implement our solution with nearly zero opportunity cost. At the same time, with modifications in the model employed, the solution can be implemented in educational campuses, and other campuses where network of computational devices is available in large scale.

Challenges and Strategies

Major advantage of this innovation is there are almost no challenges in implementing our solution in our target market. The only but major challenge is collecting dataset to train our AI model. For this we need to tie up with various offices across the World. Though we are just concerned about the quantity of data being transferred, authorities or administrators might not feel comfortable to let us have control on their data traffic data. To face this challenge, we have thought upon few strategies. Our client, Infosys, has branches in 14 cities with multiple office buildings in these cities. They can form a huge source of dataset for us. We plan to design a data collection portal where respondents can easily enter necessary data without any hinderance. We also plan to make MoUs with few large IT companies where we can provide them our product with concession in return to dataset for training our model.

Market Impact

Our solution, once introduced in market, will make a remarkable impact. As mentioned earlier, the installation and operational cost is almost zero. Anyone from the target market can easily implement our system. Because of this cost and resource savings, more people will be ready to implement building automation system in their buildings, which not only improves our business but also a vast amount of energy will be saved.

F. SCALABILITY AND MARKET POTENTIAL

Smart Buildings for A Smart City

Smart autonomous office buildings are the secret sauce for a smart city. IT based offices are flooding the nation. It is one of the sectors with high money flow. The scope for IT office building is really high at least for the next one decade. We have designed in such a way that it would meet the need of all kind of clients present in the market. Our design is not client-need specific. At the same time, we didn't fail to meet the expectations of our project partner. So, it is very easy to implement this kind of design anywhere in the country.

Climate responsiveness is the only factor to consider in such a case. But as we have achieved the climate responsiveness mostly through materials, just altering the materials accordingly would help us. Also, the office space within each floor is modular. It can be multiplied or reduced as per the need.

The building automation system which we propose to innovate will be of great demand in market. There is not much infrastructure to install. It is mostly software based. Hence, it is easy to implement in existing buildings as well. Also, that system is not constrained to use within IT offices. It will be of great use in spaces like Universities, Libraries, Large office spaces, etc.

CONSTRUCTION TECHNIQUE

Precast construction technique is used is flat slab systems. This has many advantages over conventional construction system. Precast technique saves time and hence reduce cost of construction in terms of material and labour.

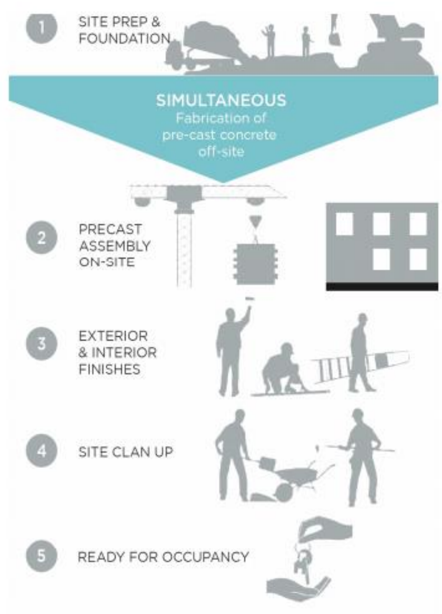


Figure 23: Stage of precast construction

Precast concrete construction is preferable because:

· Production is done in a controlled environment which improves quality

· Easier to train workers in a shop environment

· Use of Moulds costs less than the in-situ form-work which also provide dimensional accuracy

· Reduced construction time, which is of value to the developer

· Design can be optimized to desirable size, shape and finish

· Precast concrete structures provide superior resistance to fires, natural disasters, insects and mold

Figure 24: Advantages of precast construction

G. COMFORT AND ENVIRONMENT QUALITY

Passive strategies to achieve thermal comfort

Initial design annual solar radiation analysis

Through annual Radiation analysis on the building envelope on our initial design we concluded that south, east, and west façade receive most of the solar radiation.

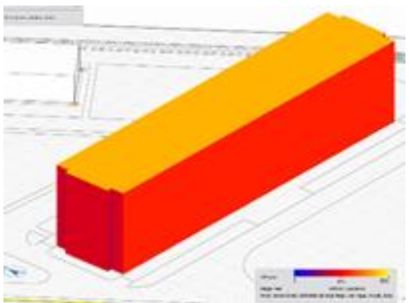


Figure 25: South and West annual radiation analysis

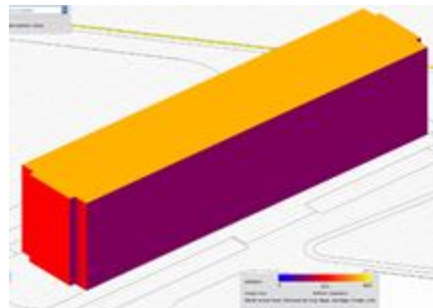


Figure 26: North and East annual radiation analysis

Longer east-west direction was chosen for this project as distribution of the solar radiation densely during the winter months and less during the summer months in the south wall, makes this orientation favorable. Glass faced has been chosen for north façade as it receives least solar radiation. South west and east walls receive most solar radiation which ultimately results in heat gain. These walls need extra insulation to avoid heat gain in the building. Selection of materials and providing extra insulation where needed was one of the key design strategies. Designing shading devices to cut off the Summer Sun and maximize the Winter Sun was needed to achieve thermal comfort.

Final design annual solar radiation analysis

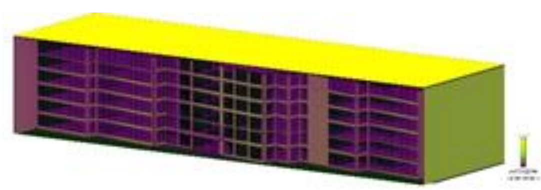


Figure 27: Solar radiation on the North building envelope

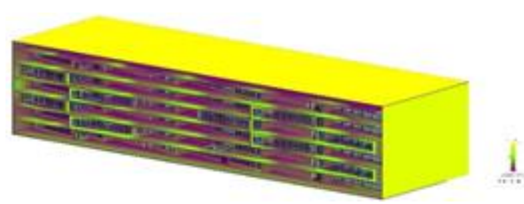


Figure 28: Solar radiation on the South building envelope

As initial analysis we concluded that south, east, and west façade receive the maximum solar radiation, we cut down the solar radiation on the southern side by using optimized shading devices on the southern façade. And protected the roof and south and west façade by using a **double skin façade element** which covers the whole building from top, east, and west side. Providing an extra layer which cuts down the solar radiation falling on the roof hence benefit in reducing heat gain and help in achieving thermal comfort. Glazing is provided in north façade to provide adequate daylight as most of the office spaces are placed along the north façade. **Light shelves** are used in this façade to provide deep penetration of day light inside the interiors.

Figure 30: south façade with optimized shading devices

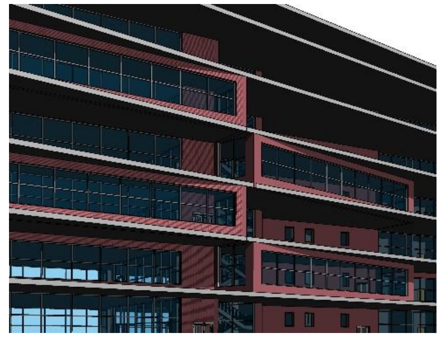


Figure 29: Facade design details with optimized shading

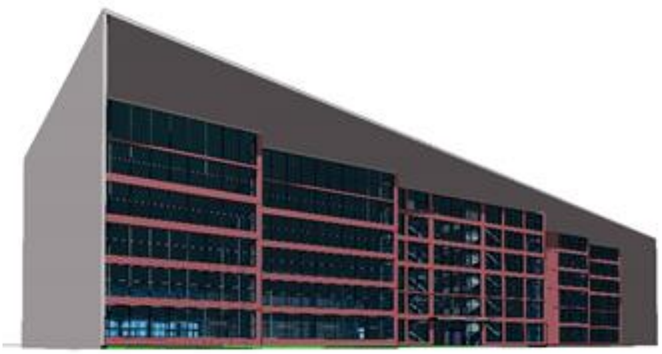


Figure 31: North facade with glazing

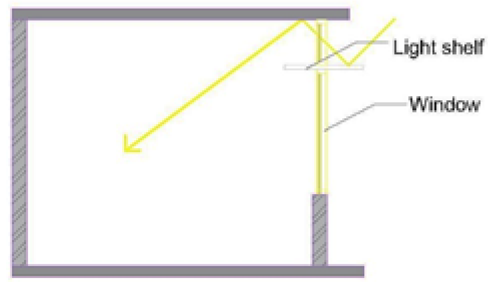


Figure 32: Light shelf for deep penetration of light

<u>Material selection strategies for Thermal comfort</u>

Wall and glazing insulation and their relative quantities mostly govern thermal performance in a building like this where length and width ratio are quite high with 5 stories and have large footprint of walls and glazing compared to roofs.

Materials for Window Assembly:

Double glazed (SunGard® extra Selective SNX 50) window with u value of 1 w/m²k and low SHGC value 0.28 and VLT of 49.6%. Composition 6mm / 16 mm / 4 mm with Gap 1 10% Air, 90% Argon.

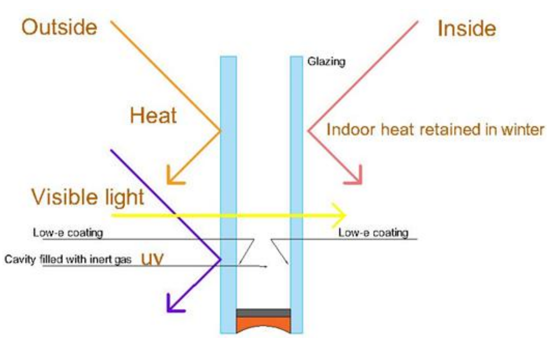
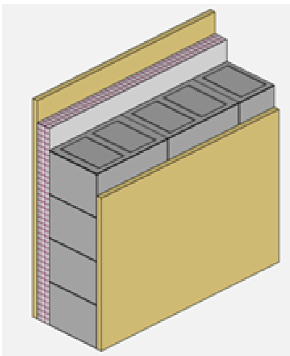


Figure 33: Double Glazed Window Details

Materials for Wall Assembly:

We used a wall assembly which contains layers of Autoclaved Aerated Concrete (AAC) Blocks, interior and exterior plaster with XPS insulation of 79.50mm thickness with 100mm brick cladding.

U-Vaue = 0.350 W/sqm-K



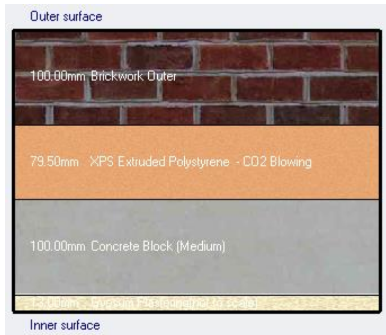


Figure 35: Wall assembly Layers

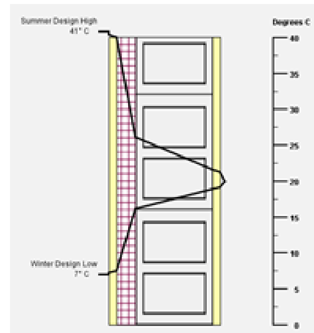
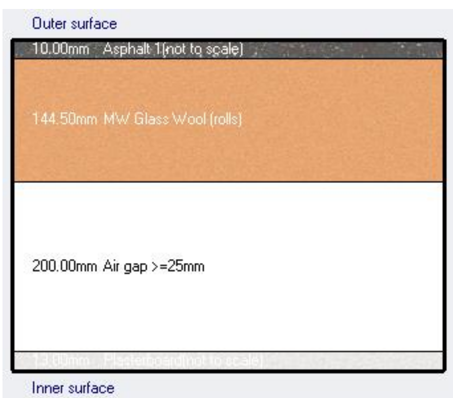


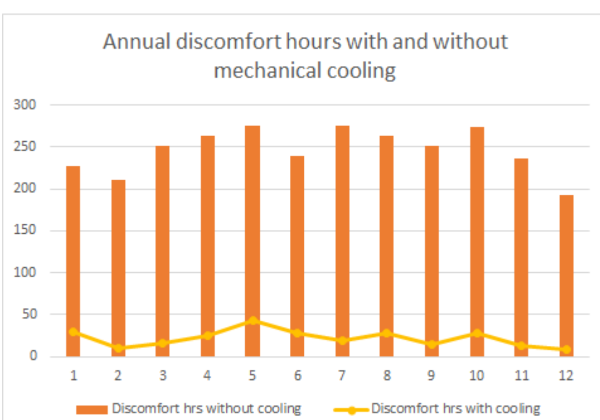
Figure 34: Wall assembly section

Materials for Roof Assembly

Reinforced cement concrete with plaster on both sides as double skin roof is being used with insulation of glass wool is provided with 10mm asphalt coating. Roof U-Value = 0.250



Annual Hours of Discomfort with and without the use of refrigerant based mechanical cooling



	Discomfort hrs with cooling	Discomfort hrs without cooling
1	29.48087	227.2577
2	9.833173	210.9242
3	15.90526	250.9449
4	25.02795	264
5	43.31011	276
6	28.13741	240
7	19.57219	276
8	27.71858	264
9	13.80207	252
10	28.79725	274.2803
11	12.91529	235.8186
12	9.226442	193.1374

Figure 36: Annual Discomfort hours with and without the use of Refrigerant based cooling.

Active strategies to achieve thermal comfort

HVAC System:

Considering climate conditions of Mohali and project partner requirements, Radiant Cooling System integrated with a Dedicated Outdoor Air System (DOAS) for cooling and ventilation is used in this project.

- **Radiant Cooling System:** Thermally Activated Building System (TABS) is a combined heating and cooling system with pipes embedded in the structural concrete slabs or walls of Multi-Storey buildings. TABS operates at temperature close to ambient enabling more efficient utilization of renewable and free cooling sources. Moreover, it provides optimized thermal indoor environment.
- **Dedicated Outdoor Air System (DOAS):** A DOAS provides fresh dehumidified air to the building. Radiant cooling system removes only sensible heat from the building but to handle latent heat loads DOAS system is required.

Natural ventilation

- **Orientation:** Building is oriented in prevailing wind direction which provides maximum ventilation to the building.
- **Building shape:** thinner building shape is used in the design to increase the ratio of surface area to volume which is helping in ventilating building naturally. This strategy not only helps in cross ventilation but also helping in stack effect.
- **Operable windows:** South façade window inlets are operable which allows to adjust the flow of fresh air inside the building

Mechanical ventilation

It is used in the building to improve indoor air quality, and control humidity, odors and contaminants through dilution and replacement with outside air.

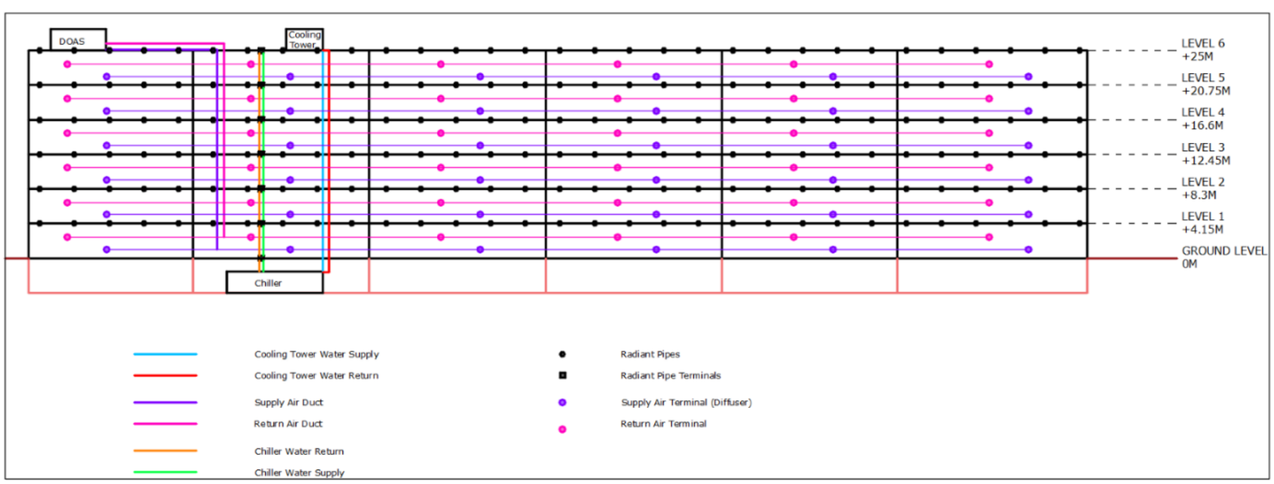


Figure 37: HVAC System Section Diagram

Night flushing:

It is a passive cooling method which allows wind to create thermally initiated pressures. The heat which is absorbed by building envelope in daytime released in indoors during nighttime which is flushed by night ventilation. Automatically operable windows and ventilators and louvres being opened for a pre-set period of time over night, allowing a natural air flow through the building.

Site, Landscape and Urban design strategies for achieving reducing thermal stress in the outdoor environment:

Site vegetation and landscape elements affect the outdoor thermal comfort for the encompassing buildings in composite climate like Mohali. In order to improve the outdoor thermal environment of attached urban morphologies in Mohali Infosys Campus, the streets and the spaces between buildings must be taken into account in the urban and landscape design processes.

Vegetation is used in design for energy conservation in our office building in the following ways:

- Shading of buildings and open spaces through landscaping with native plants
- Terrace gardens with adjacent workspace
- Shading of vertical and horizontal surfaces
- Buffer against cold and hot winds
- Changing the wind direction

Landscape and vegetation also alter the micro-climate of our design site and was used as micro-climate manager for as long as buildings have been built. This was possible through evapotranspiration.

Plantation also shading building surfaces in west and southern facade and open ground, thus inducing lower surface temperatures and it does not vary much even when exposed to harsh radiation occasionally during hot seasons. we are considering semi outdoor terrace gardens for reducing heat loads in office workspace and working as shading devices for our façade. The green cover lowers ambient temperatures through evapotranspiration.

As the entrance is in the north façade which will be shaded by building shade through during the harsh hours of the day. There is a water body on the northern side of the façade which is helping in evaporative cooling.

H. ARCHITECTURE DESIGN

Concept:

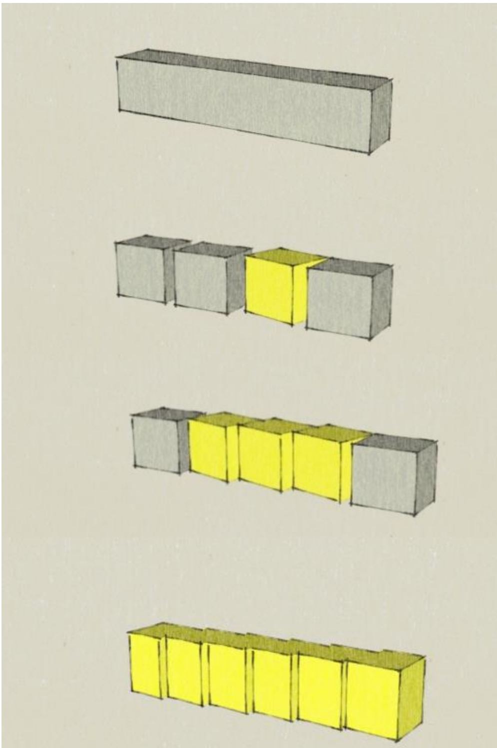


Figure 38: Concept Design

1. The Idea was to get the minimum sun exposure of the building during summer and maximize during Winter season.

2. The Building was imagined as set of cuboids. Each of the cube was examined through heat gain simulation. The orientation of the cubes was set as the best orientation throughout the year.

3. Each of cuboid was affecting the immediate cube in terms of best orientation set up.

4. calculating all the possible angles the form all best orientation the form gets the feature like this

Building Elevations:

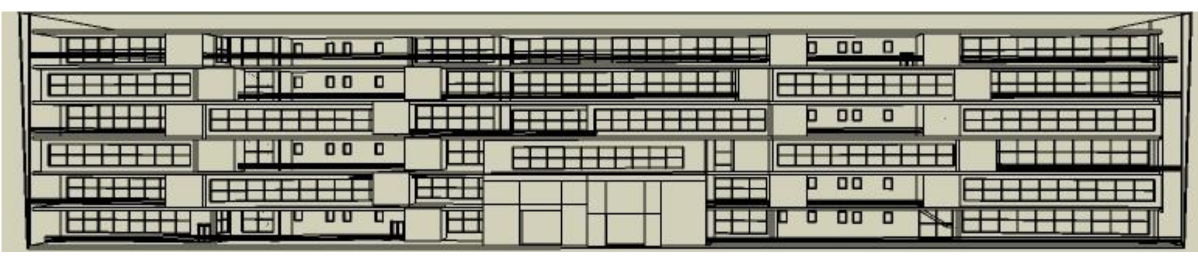


Figure 39: South Elevation

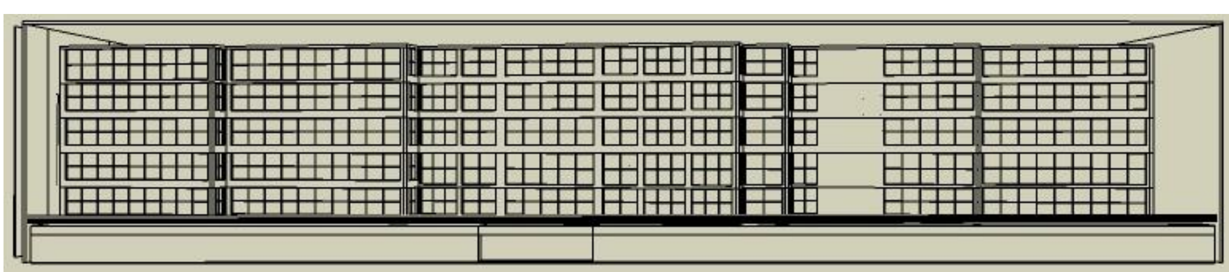


Figure 40: North elevation

Visualizations:

Figure 41: Birds eye view from southern side

Figure 42: View form South-East

Figure 43: View from North-west

Figure 44: View from North-east

Architecture Plans:

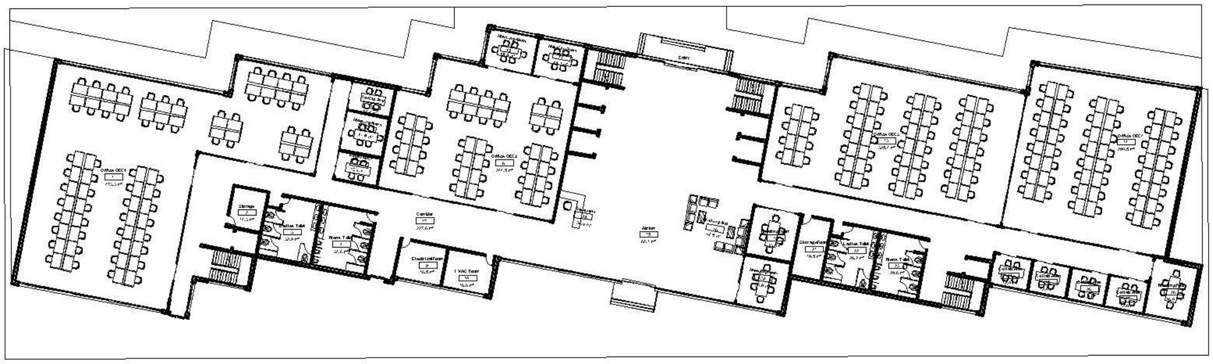


Figure 45: Ground Floor Plan

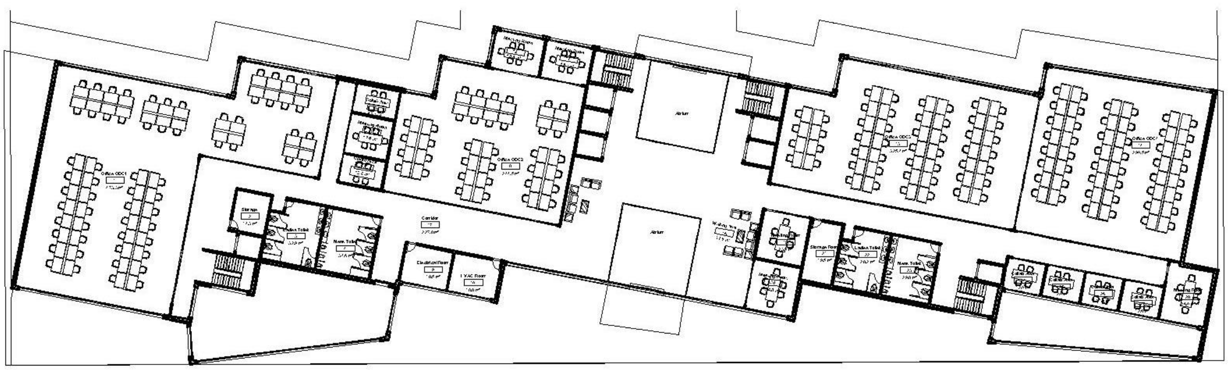


Figure 46: First Floor Plan

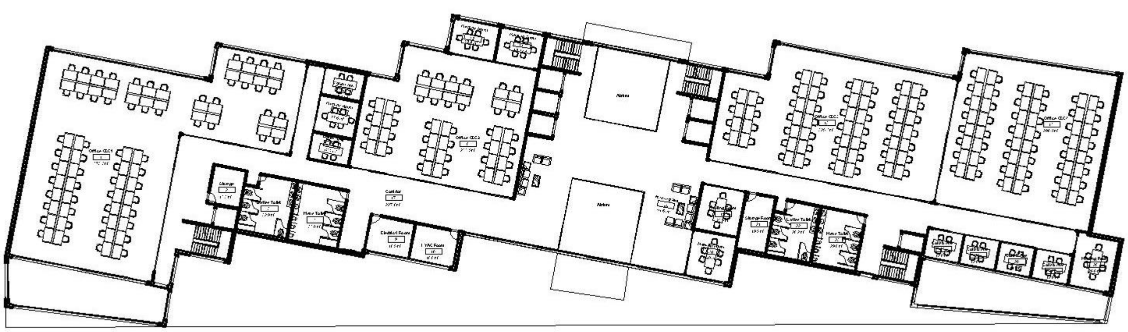


Figure 47: Second Floor Plan

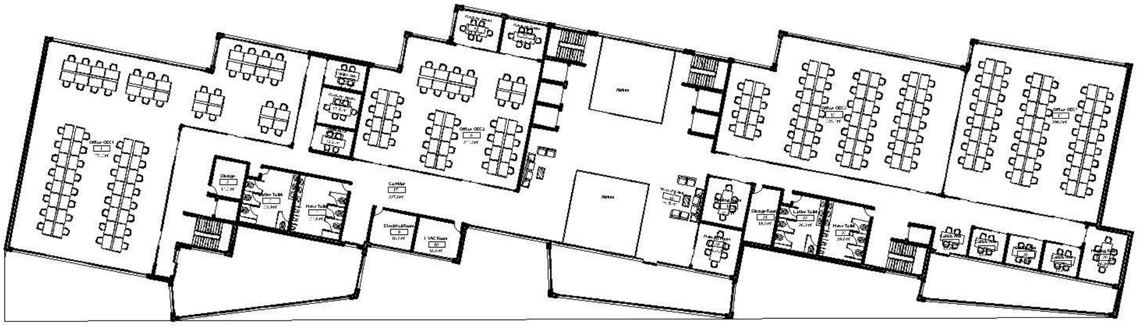


Figure 48: Third Floor Plan

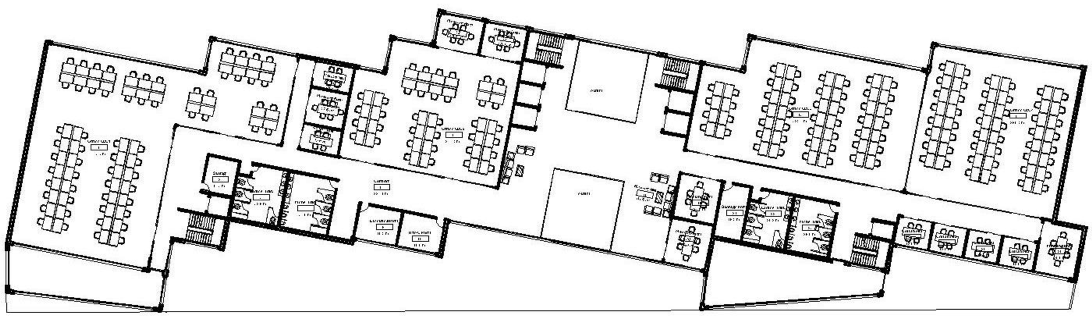


Figure 49: Fourth Floor Plan

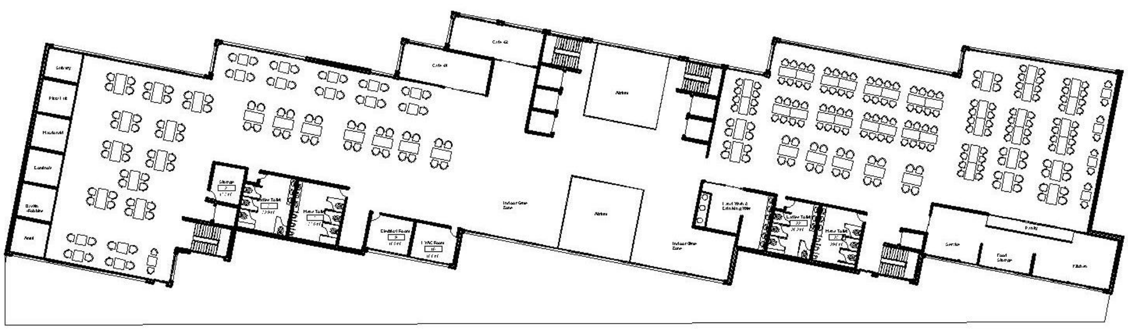


Figure 50: Fifth Floor Plan

I. ENGINEERING DESIGN AND OPERATION

Proposed Construction Materials:

1. RCC Framed Structure- Flat slab system
2. AAC Blocks for exterior walls
3. Drywall for interior partitions
4. RCC slab for floor and roof
5. Low-e double glazed glass for glazing

RCC Framed Structure - Flat Slab System:

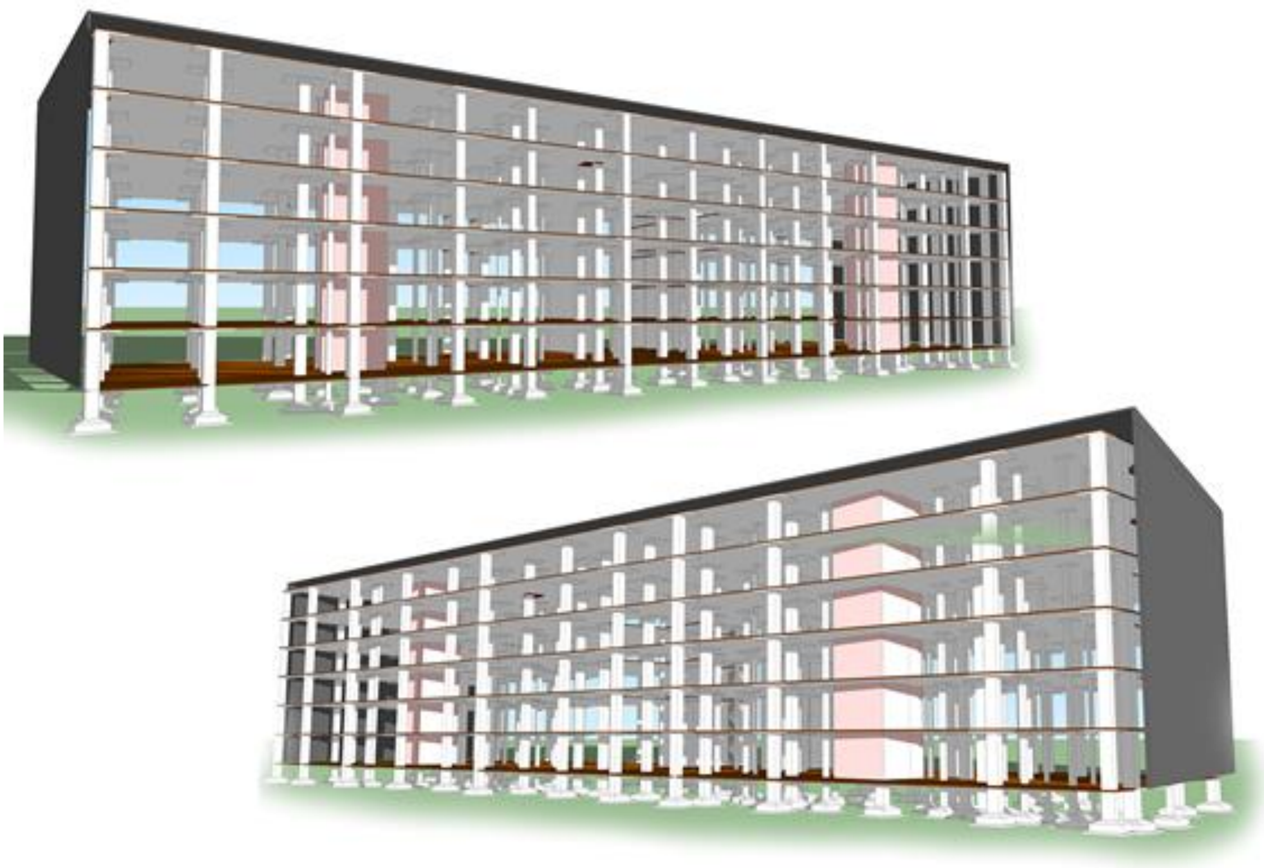


Figure 51: View of Structural elements

Flat Slabs without drop panels are introduced in the design, which can be built at a very **fast pace** as the framework of structure is simplified and diminished. Also, speedy turn-around can be achieved using an arrangement using early striking and flying systems.

Flat slab construction is deeply **reducing floor-to –floor height** as flat slab construction does act as limiting factor on the placement of horizontal services and partitions.

In case the client plans change in the interior and wants to use the accommodation to suit the need, flat slab construction is the perfect choice as it offers that **flexibility** to the owner. This flexibility is possible due to the use of square lattice and absence of beam, hence making channeling of services and allocation of partitions easy.

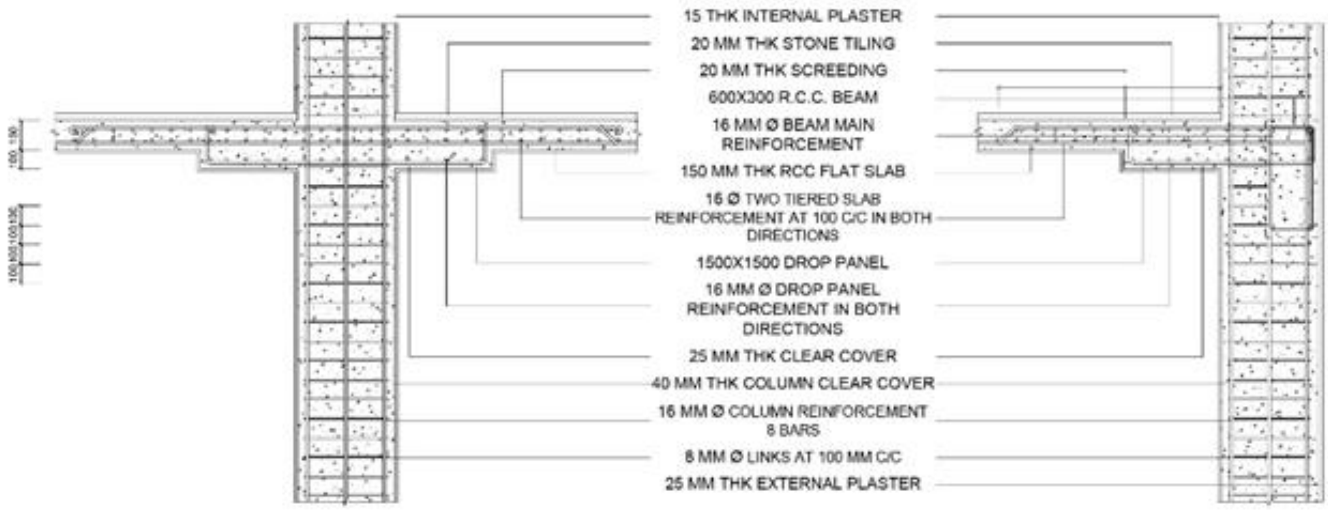


Figure 52: Column and slab section

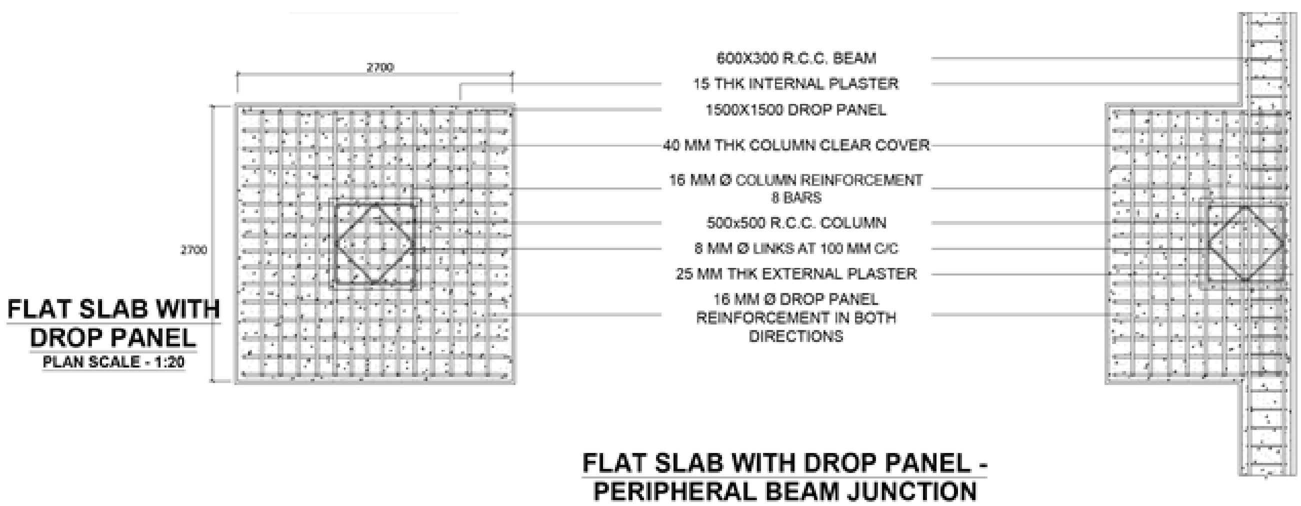


Figure 53: Column and slab plan

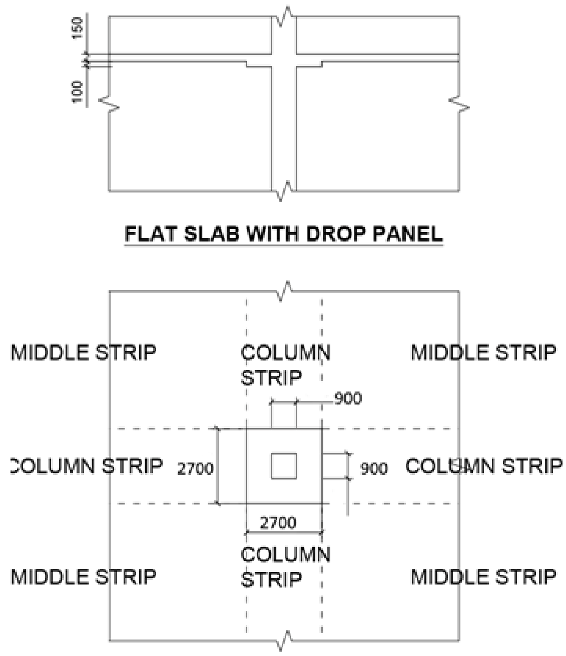


Figure 54: Column and drop panel details

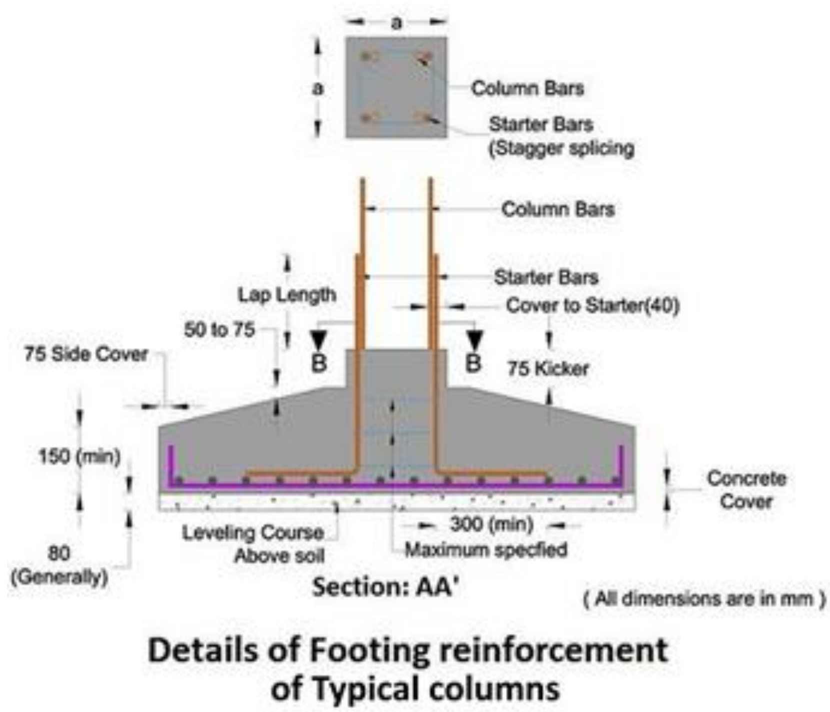


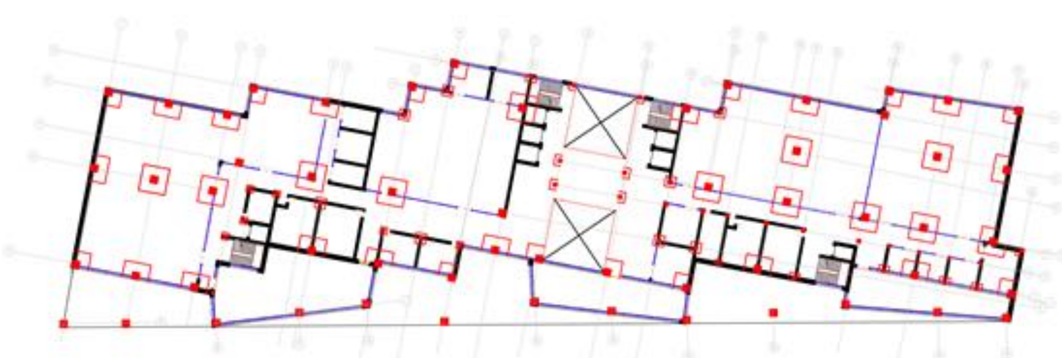
Figure 55: Footing section

Building Structural Layouts

Ground Floor

First Floor

Second Floor



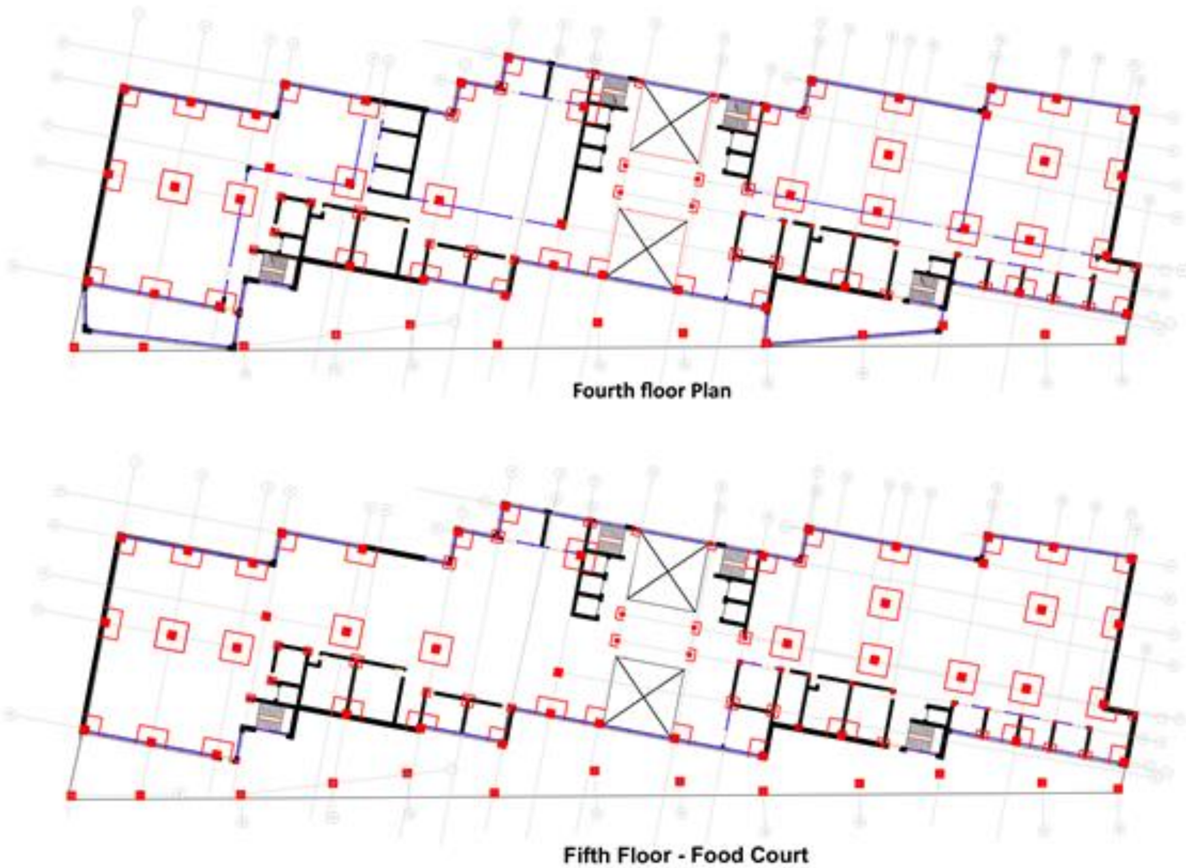


Figure 56: Building Structural Layouts

Other Building Structural Elements

<u>AAC Blocks for exterior walls</u>

AAC is lightweight precast foam concrete. Its advantages are:

Lightweight

AAC Blocks are three to four times lighter than traditional brick; therefore, more suitable and cheaper to transport Block weighs approximately 50% less than standard concrete masonry block, and usage reduces the overall dead load of the building thereby allowing construction of the taller building

Easy Workability and design flexibility

Blocks can be easily cut drilled nailed and grooved to fit individual requirements available in custom sizes simplifies hydro sanitary and electrical installations such as pipes or ducts, which we can install after the completion of the leading construction.

Faster Construction

Reduces construction time by 20% different sizes of blocks helps reduce the number of joints in wall masonry, lighter blocks facilitate more comfortable and faster construction. These blocks are easy to install also sets and hardens quickly.

Minimum Wastages

AAC blocks have negligible breakage less than 5%; hence utilization of blocks increases.

Thermal insulation and energy-efficient

These blocks allow excellent thermal insulation due to tiny air pores and thermal mass of blocks. Hence helps in reducing heating and air conditioning costs of a building.

Eco friendly and sustainable

Mix productive use of recycled Industrial waste is a fly ash non-polluting manufacturing process. The only by-product is steam made of non-toxic ingredients that do not exist gasses.

Acoustic performance

Superior sound absorption qualities due to the porous structure of block offer sound attenuation of about 42 decibels blocking out all significant sounds and disturbances.

Fire-resistant

AAC blocks are non-combustible and fire-resistant up to 1600 degrees Celsius. These blocks are fire-resistant approximately 2 to 6 hours, depends on the thickness of the Wall.

Cost-saving

The requirement for plaster on AAC blocks is less due to the surface accuracy of the blocks, thus reduces overall construction cost by 2.5 %. Since it requires less jointing hence minimizes the demand for cement and steel. AAC block has high insulation properties, which help in saving energy costs by almost 30%.

Seismic resistant

The manufacturing process gives the blocks excellent strength maintaining its lightweight property due to which the steadiness of these blocks in buildings is more reliable, making it earthquake resistant.

Accuracy

ACC blocks offer high precision in size. Blocks are available in exact dimensions to provide a smooth wall with a perfect joint between different elements. It also helps to save cement and steel usage.

Termite pest-resistant

The blocks are made with inorganic materials; hence it keeps termites away, avoiding damages and losses.

Water saver

AAC Block walls do not require water for curing. Only the mortar joints need water for curing, thus reduces water consumption.

Drywall for Internal Partitions:

Affordability
Drywall and Drywall service is affordable for just about everyone. Its cost efficiency makes it a highly popular choice for homeowners. It is much more affordable than plaster walls or paneling. Combine the affordability of drywall with its ease of installation and repair, and it makes for a wildly popular choice. Not only is the drywall itself affordable, but so is the repair or replacement of it.

Beauty and Elegance
There is a simple yet elegant beauty to drywall for homes or offices. It can be painted multiple times, allowing you to change the look and feel of a room quickly and easily. When properly installed, drywall is easily one of the best-looking materials available and affordable for most people. Get in touch with a drywall contractor or drywall expert for service today.

Insulation Properties
When it comes to insulation, not many affordable materials can compare to drywall. It helps any room retain its temperature, whether it’s cold air or warm air. Improved insulation will not only make your rooms cozier and more comfortable; it will also lower your energy bill costs all year long. Heaters won’t need to work as hard to keep rooms with drywall warm. The same is true for air conditioners and drywall. A competent drywall technician can explain this to you further.

Fire Resistant Properties
Drywall slows down the spreading of fires. This greatly aids in the containment of fires in your home or office. The safety benefits of drywall alone make it well worth the cost, which is already low! Drywall can slow down a fire and potentially save your home or office from further damage. Furthermore, it may even aid in the saving of the most precious commodity on the planet; life. Always call a credible company for drywall installation and repair service.

Ease of Repair and Installation
Drywall is easy to install for professionals, which helps make it a very popular choice. Not only is the installation fast and easy, but repairs can be performed much easier than many other wall materials. Drywall is installed in large sections. But can be repaired without replacing the entire section due to various techniques used by pros.

Low-E- Glazing:

Features
- Low U-Values
- Superior aesthetic
- Diverse ranges of reflectivity
- Insulating laminated, heat strengthened and bent glass available
- Extensive range of colors, patterns, and designs for different projects.

Advantages
- Heat control and energy e-fficiency
- Protection against UV radiation
- Optimum light transmission
- Provides maximum daylight, transparency and improves visibility.

Building Materials:

Materials	Elements	U-Value	Rates
Struct. Frame	RCC	U value - 0.5 W/m^{2}K	Rs.15000/cu.m
Ext. Wall	AAC	U value - 0.08 W/m^{2}K Thickness - 10inches	Rs.2800/cu.m
Int. partition wall	Drywall (Best for acoustics)	Wall thickness - 144mm Acoustics - 58 Rw Fire resistance - 60mins Weight - 47 kg/m^2	
Int. partition wall	Drywall	Wall thickness - 100mm Acoustics - 47 Rw Fire resistance - 60mins Weight - 38 kg/m^2	
Glazing		Low Iron + Low Iron Visible (Trans.) - 80.0% Visible (Refl.Ext.)- 14.0% Visible (Refl.Int.) - 14.0% Solar (Trans.) - 65.0% Solar (Refl. Ext.) - 20.0% U value (Winter) - 0.32 U value (Summer) - 0.31 SC - 0.78 SHGC - 0.68 LSG - 1.18	
Floor	RCC Slab	U value - 0.8 W/m^{2}K Thickness - 6inches	
Roof	RCC Slab with Polyisocyanurate (PIR) insulation	Slab thickness - 6inches PIR thickness - 1inch U value of system - 0.15 W/m^{2}K	

Table 6: Building Materials

HVAC system

In Mohali, the summers are short, sweltering, and clear and the winters are short, cool, dry, and mostly clear.

As it is an office building, internal thermal load is higher than external thermal load because of denser occupancy and a greater number of electrical and electronics appliances.

As per the climatic conditions of Mohali and the project partner requirements, it is decided to use a Radiant Cooling System integrated with a Dedicated Outdoor Air System (DOAS) for cooling and ventilation purposes respectively. As the occupancy is high, latent heat load is high inside and radiant cooling system cannot take care of latent head load, DOAS is necessary.

Radiant Cooling System:

There are different types of radiant systems. But here we are using a Thermally Activated Building System (TABS).

The Thermally Activated Building System (TABS) is a combined heating and cooling system with pipes embedded in the structural concrete slabs or walls of multi-Storey buildings. TABS operates at temperature close to ambient enabling more efficient utilization of renewable and free cooling sources. Moreover, it provides optimized thermal indoor environment.

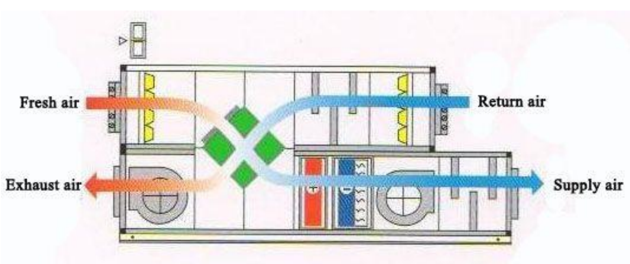


Figure 58: Flow in typical DOAS

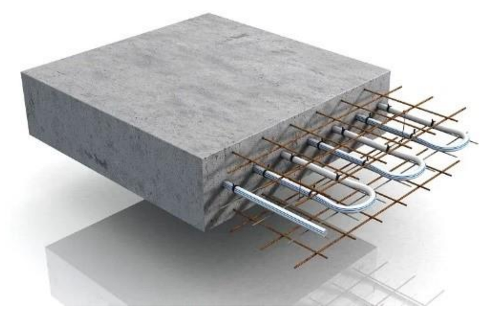


Figure 57: Thermally Activated Building Systems (TABS):

DOAS:

Radiant systems can only remove sensible loads from the building. To handle latent loads a DOAS needs to be installed. A DOAS provides fresh dehumidified air to the building.

An Energy Recovery Wheel (ERW) or Enthalpy wheel is also to be used in DOAS to utilize the useful energy from the return air. Rather than discard used building air, an enthalpy wheel salvages useful energy and transfers it to incoming, fresh air.

The summary of design load calculations and system sizing is given below.

Air System Information

Air System Name	Radiant System		Number of zones	1	
Equipment Class	TERM		Floor Area	102970.0	ft²
Air System Type	ACB		Location	New Delhi, India	

Sizing Calculation Information

Calculation Months	Jan to Dec
Sizing Data	Calculated

Cooling Coil Sizing Data

Total coil load	227.8	Tons	Load occurs at	Jul 1500	
Total coil load	2734.1	MBH	OA DB / WB	107.0 / 72.0	°F
Sensible coil load	2295.4	MBH	Entering DB / WB	107.0 / 72.0	°F
Coil CFM at Jul 1500	39275	CFM	Leaving DB / WB	51.5 / 48.7	°F
Max coil CFM	39275	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.840				
Water flow @ 10.0 °F rise	547.11	gpm			

Heating Coil Sizing Data

Max coil load	169.2	MBH	Load occurs at	Jun 0500	
Coil CFM at Jun 0500	39275	CFM	Ent. DB / Lvg DB	51.4 / 55.5	°F
Max coil CFM	39275	CFM			
Water flow @ 20.0 °F drop	16.93	gpm			

Ventilation Fan Sizing Data

Actual max CFM	39275	CFM	Fan motor BHP	53.78	BHP
Standard CFM	38281	CFM	Fan motor kW	42.66	kW
Actual max CFM/ft²	0.38	CFM/ft²	Fan static	5.00	in wg

Exhaust Fan Sizing Data

Actual max CFM	39275	CFM	Fan motor BHP	16.13	BHP
Standard CFM	38281	CFM	Fan motor kW	12.80	kW
Actual max CFM/ft²	0.38	CFM/ft²	Fan static	1.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	39275	CFM	CFM/person	20.48	CFM/person
CFM/ft²	0.38	CFM/ft²			

Figure 59: HVAC System Design Load and System Sizing Summary

HVAC Single Line Diagram

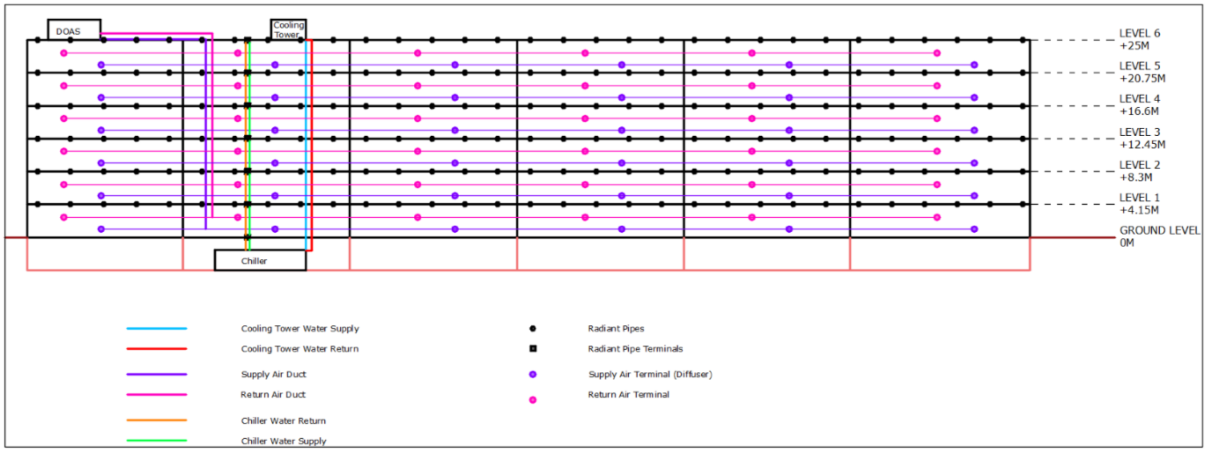


Figure 60: HVAC Single Line Diagram - Section

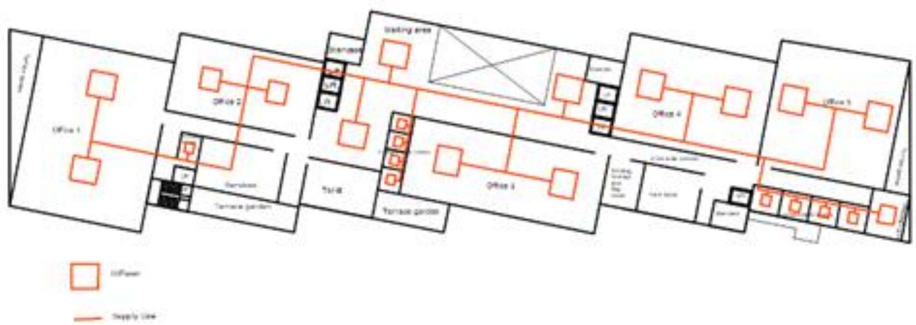


Figure 61: HVAC Single Line Diagram - Plan

Electrical System

On grid solar power plant of capacity 150 kWp will be installed. The single line diagram of each floor is shown and power consumption of each floor is mentioned.

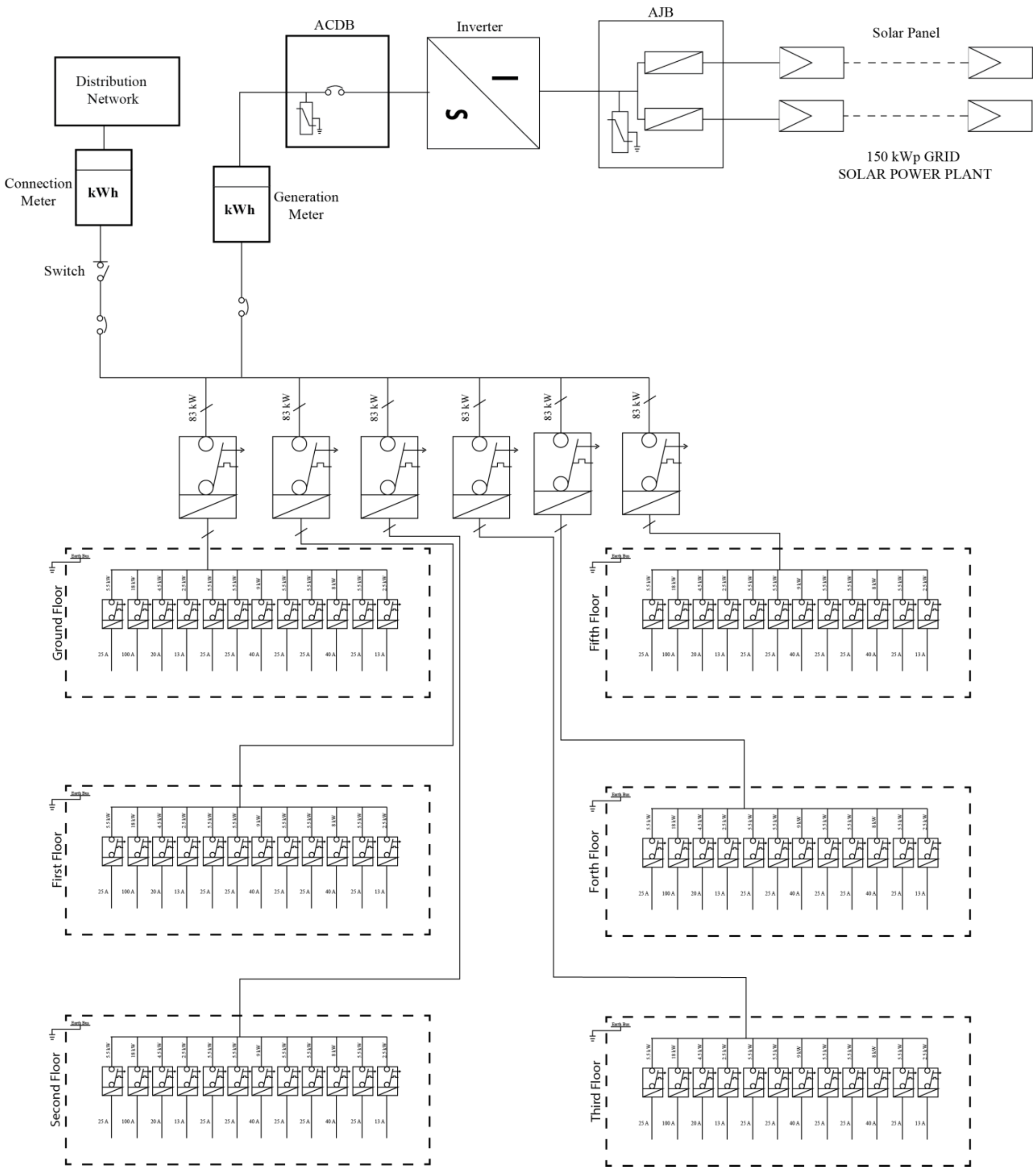


Figure 62: Electrical Single Line Diagram

10. PITCH YOUR PROJECT PARTNER

What are we proposing?

The proposal contains a design ready net zero energy and water building, it does not only support to sustain the environment in which we live but also provides resources for our daily needs without being exploiting it from the mother nature. The additional benefits are towards operational cost reduction by reducing the energy demand to significant amount.

How have we achieved this?

The steps towards a net zero energy and water building started with the understanding of site climate, design requirements, available renewable resources, and economic benefits towards operational expenses.

The provided solutions are the practical integration of different functional components towards the requirements.

Steps towards achieving a net zero energy building.

- **Design considerations from the very beginning.**

The design considerations from the initial stages helps reduce the additional cost which we need to put in the construction and get back as payback later. The earlier you start considering the net zero energy approach the easy and economical it will achieve it.

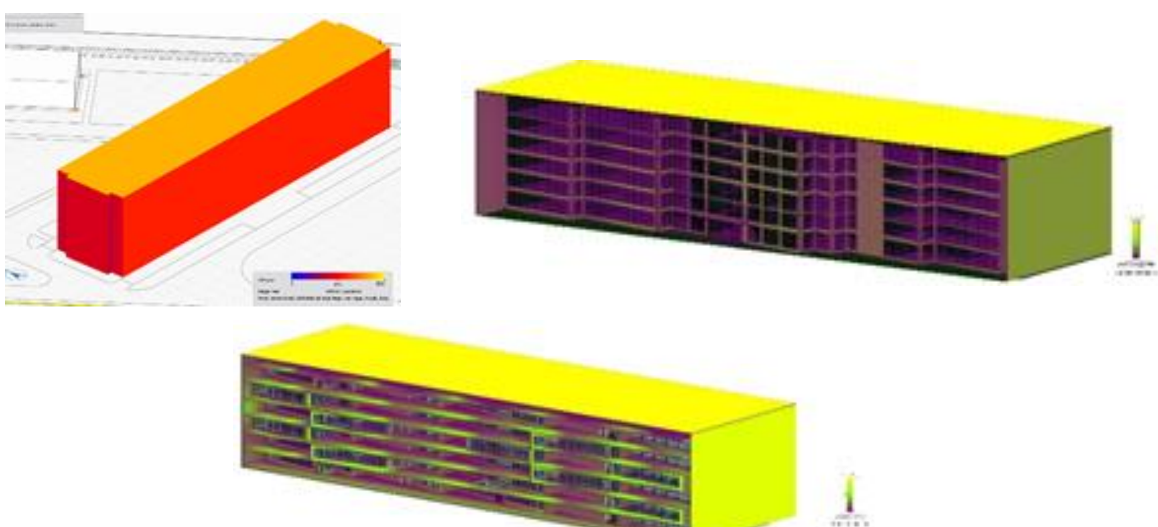


Figure 63: Orientation and Envelop Analysis from initial design stages

- **Façade and envelope optimization for reducing the heat and lighting load.**
  Energy demand calculations are done at initial stages which acts as benchmark and it is reduced to match the energy generation through optimized fenestration ratio and efficient building envelop.

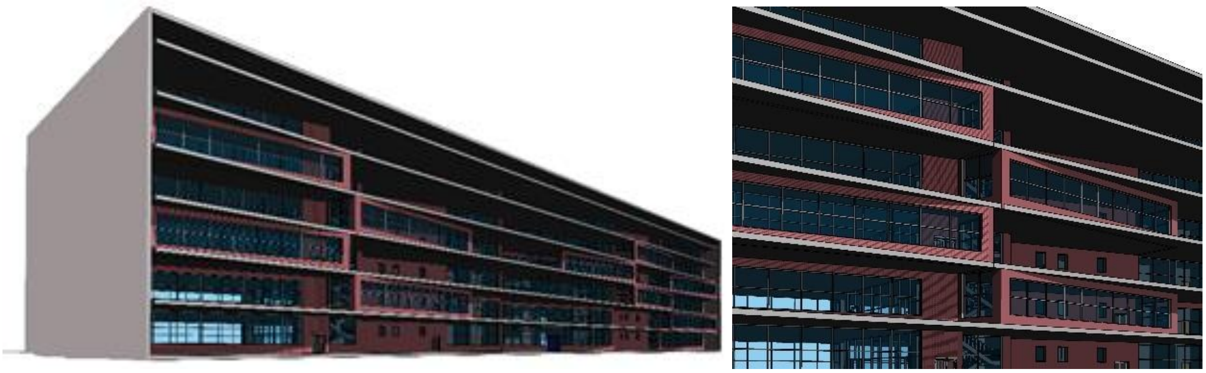


Figure 64: Facade fenestration and envelope optimization through shading and reducing window-wall ratio.

These are the initial load reduction by design considerations which helps to achieve lower operational costs.

Steps towards achieving a net zero water building.

- On-site resource calculations

Available amount of annual rainwater harvesting is calculated and and is compared with the demand and recycled water is supplied to possible area

- Reduction techniques

To match the demand with the harvested amount of rainwater water efficient fixtures are used.

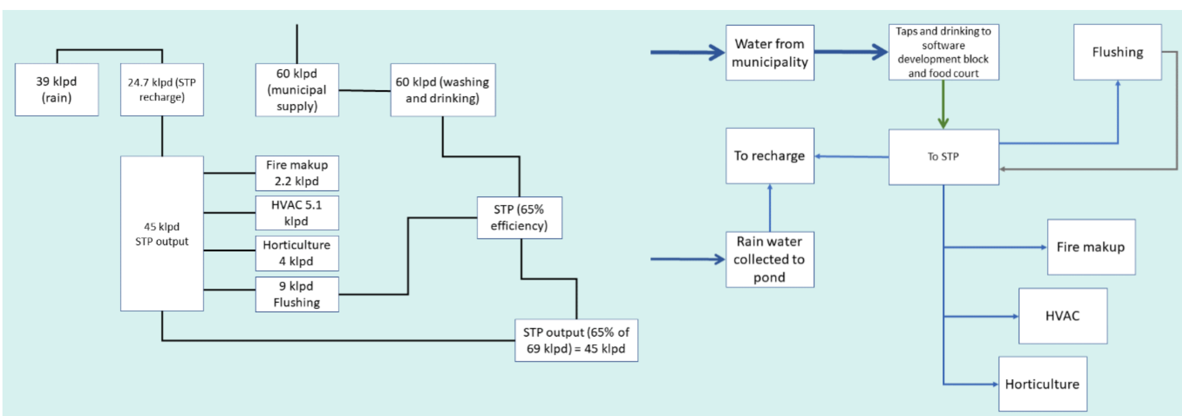


Figure 65: Water Cycle, Collection and Demand

Cost analysis

The operational cost has a significant share in the life cycle cost of the building, since Infosys owns and operates the building, its beneficial to pay lower operational cost throughout the life of building with nominal additional construction expenses.

For office typology of buildings, the operational costs are more significant as its important to achieve the required level of comfort to create a healthy and comfortable environment.

11. APPENDIX B

भारतीय प्रौद्योगिकी संस्थान रुड़की
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Dated:Oct/09/2020

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This is to certify that Priya Patel *S/O or D/O* ✓ Hukum chand Patel*, bearing Roll Number* 2011 2 0014 *is a bonafide student of National Institute of Technology, Tiruchirappalli, pursuing* M. Arch *in* Energy Efficient & Sustainable Architecture *currently* 1st *year,* 1st *semester.*

Signature of the HoD
Dr. G. Subbaiyan