Energy Conservation Through Passive Ventilation in an Office Building

[1]Narendra Mandala, [2]Ananya Das

[1]Architect, [2] Architect and sustainability consultant

ABSTRACT:

Globally, the building sector is the single largest consumer of energy. A major share of carbon emissions and Greenhouse gas emissions may also be attributed to the building sector. It may be observed from several studies on energy consumption break-up for office buildings, that HVAC consumes the majority of the energy in an office building. Hence, by integrating a building with efficient and adequate passive ventilation strategies, one can reduce the building's total energy demand thereby reducing dependence on finite resources and subsequent carbon emissions from their processing. Although passive ventilation cannot replace or eliminate the use of artificial ventilation, it can be used as an effective means of ventilation in small scale government office buildings. In this research,

***Index Terms* – Office Building, Passive Ventilation, Stack, Solar-Chimneys, Solarium, Energy Efficiency.**

INTRODUCTION

Ventilation plays an essential role in achieving the well-being of a building. Ventilation in a building is allowing the air to circulate in the space to enhance air exchange also adequate thermal comfort inside the building. It can be achieved through an active or mechanical way or as passive ways. Passive ventilation is the technique of allowing the natural air inside the room and removing it without using any mechanical systems. To achieve this type of ventilation, several passive strategies can be adopted for the designed spaces. In this research wind-driven ventilation system has been taken into consideration with adequate size and positioning of the openings along with other strategies like solar chimneys, solariums, and Jali-walls to achieve required natural ventilation inside the space without using a mechanical ventilation system to analyze the reduction in energy consumption of the same volume of space ventilated through mechanical ventilation systems.

1. SITE ANALYSIS

1.1. Proposed Site

The existing site is in Ahmedabad, Gujarat, India, which has been considered for the research purpose only to see how the ventilation can work at its extreme period in such a climatic condition.

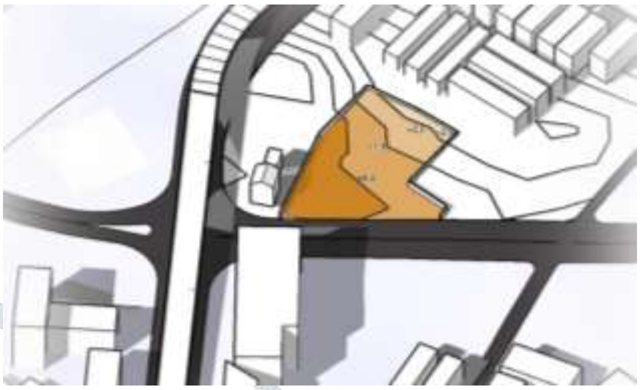

Figure 1. The Proposed Site View from the North-East Direction (from the road to the site).

The site area is 6138.42 sq.m (1.52 ac.) & has 2.50m contours from east to west

1.2. Climate analysis


CLIMATE ANALYSIS

Figure 2. Climate Analysis.

1.3. Site Simulations

Wind Analysis for the site concerning the prevailing wind conditions and the impact of the Surroundings on the Site.

Figure 3. Wind velocity and flow on the site.

Wind velocity and direction on the site, the Prevailing wind direction is from North, where Natural Wind Speed is 1m/s but due to the influence of the surrounding buildings, the onsite wind Speed is 0.6m/s, which is also directing the wind on-site from North-East direction.

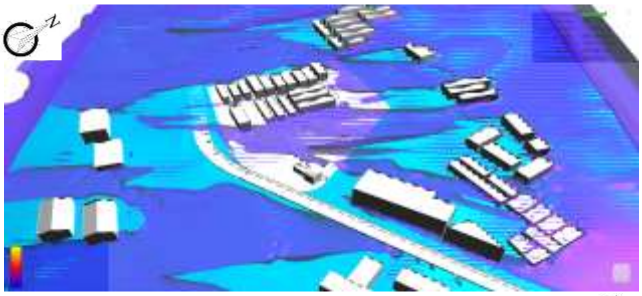

Figure 4. The Velocity of the Wind on the Site.

The Velocity of the Wind on the Site, the Prevailing wind direction is from North, where Natural Wind Speed is 1m/s but due to the influence of the surrounding buildings, the onsite wind Speed is 0.6m/s.

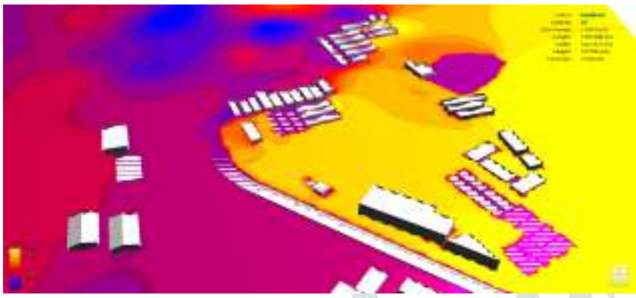

Figure 5. Wind pressure on the site.

Wind pressure on the site, the Prevailing wind direction is from North, where Natural Wind Speed is 1m/s and the onsite Wind Pressure is 8 Pa.

South-West Wind

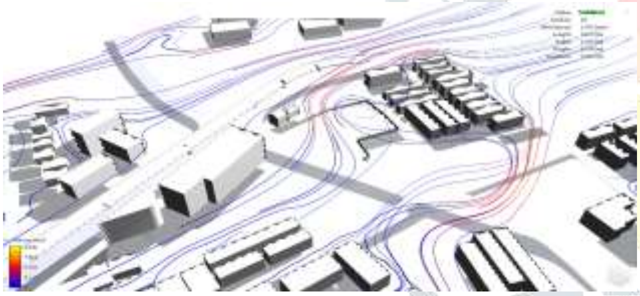

Figure 6. Wind velocity and flow on the site.

Wind velocity and flow on the site, the Prevailing wind direction is from South West, where Natural Wind Speed is 2m/s and the onsite Wind Speed is 1m/s, but the wind direction changes to South on-site due to influence of surrounding buildings.

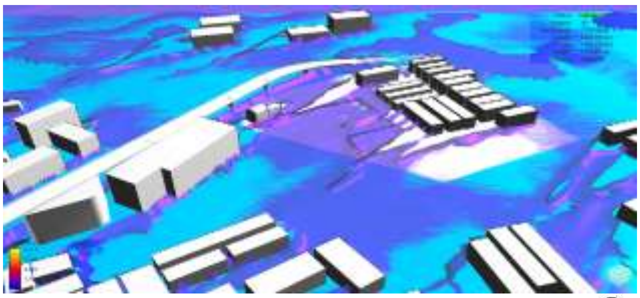

Figure 7. The Velocity of the wind on the site.

The Velocity of the wind on the site, the Prevailing wind direction is from South West, where Natural Wind Speed is 2m/s and the onsite Wind Speed is 1m/s.

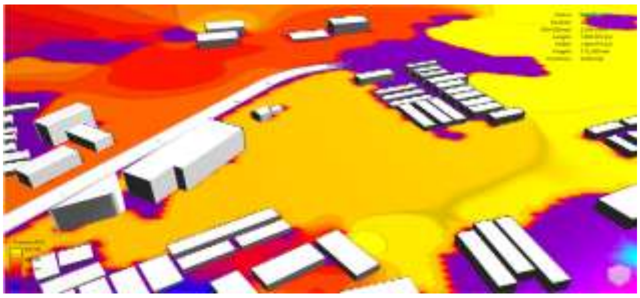

Figure 8. Wind pressure on the site.

Wind Pressure on the Site, the Prevailing wind direction is from South West, where Natural Wind Speed is 2m/s and the onsite Wind Pressure is 50 Pa.

2. PROPOSED DESIGN OF AN OFFICE BUILDING

The office building is three floors building placed centrally in the site with main its main entrance facing the Northeast direction.

2.1. Concept Development

The building has been conceptualized according to the orientation of the site and according to the climatic condition of the place.

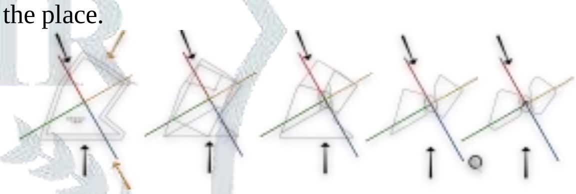

Figure 9. Concept development.

Predominantly the suitable parameters of the Wind direction and the sun path have been considered for the design of the office building.

2.2. Floor Plans

The figures below show the floor plans of the office building.

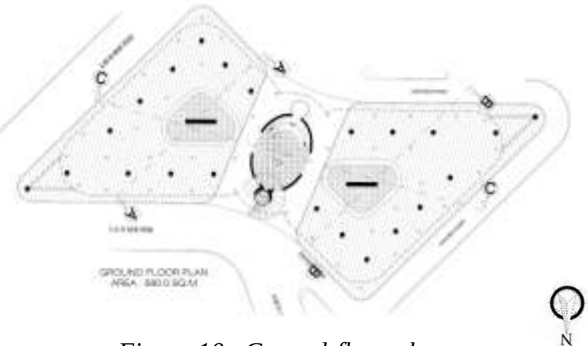

Figure 10. Ground-floor plan.

The ground floor of the office building comprises of the entrance lobby and reception.

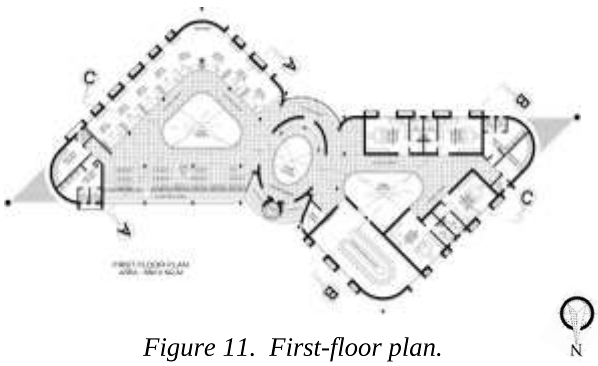

Figure 11. First-floor plan.

The first floor of the office building comprises of the open offices, waiting lobby, office cabins, conference room, pantry, and respective common toilets.

Figure 12. Second-floor plan.

The second floor of the office building comprises of the office cabins, conference/seminar hall, surveillance/server room, pantry, storage, records room, and open terrace garden as well.

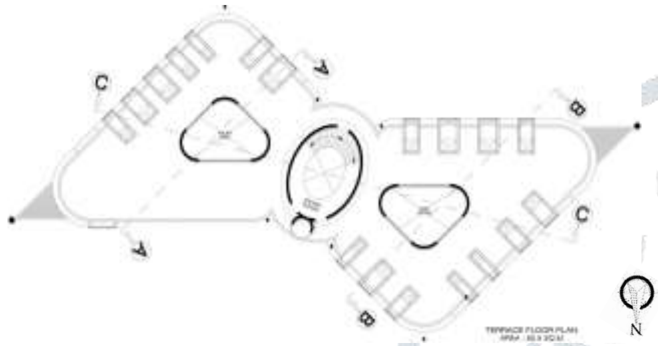

Figure 13. Terrace-floor plan

2.3. Columns

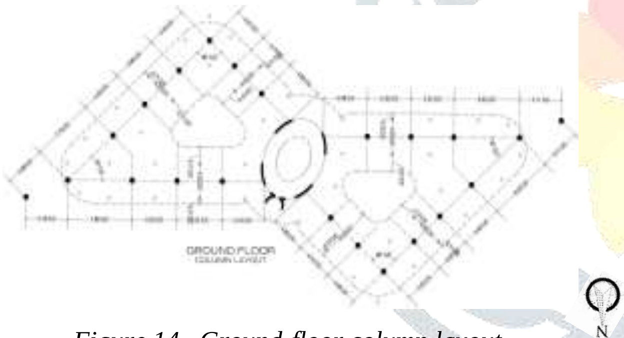

Figure 14. Ground-floor column layout.

The figure above shows the ground-floor plan with the column layout of the office building.

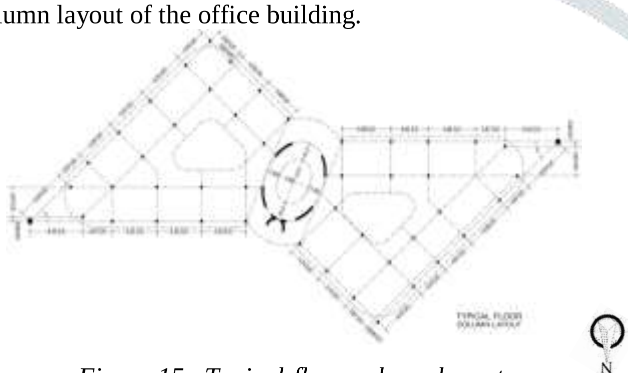

Figure 15. Typical-floor column layout.

The figure above shows the typical-floor plan with the column layout of the office building.

2.4. Elevations

The below figures show the elevation of the office building wherein the main façade solar chimney alignment and positioning can be seen along with the purposeful design of the Jali walls.

Figure 16. North elevation (front).

Figure 17. South elevation.

Figure 18. East elevation.

Figure 19. West elevation.

2.5. The sections

In the section below of the office building, the section can be found through the solariums and chimneys.

Figure 20. The section at A-A'.

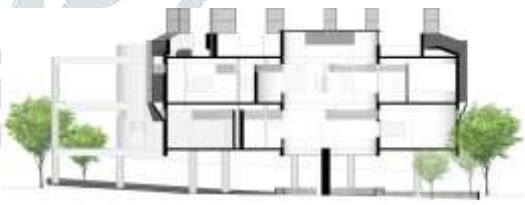

Figure 21. The section at B-B'.

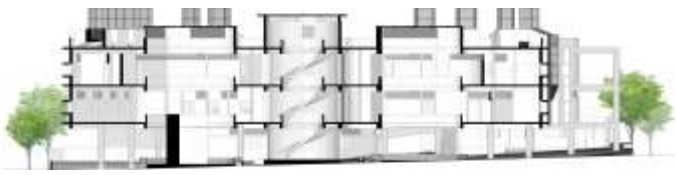

Figure 22. The section at C-C'.

2.6. Site Plan

The main entrance to the site of the office building complex is oriented facing the main abutting road towards the North-East direction.

Figure 23. Site plan.

The site has been provided with a single entry-exit according to the scale of the campus designed and the vehicles of the occupants/users. A green buffer space (interactive open space) with water features has been provided to avoid the noise and pollution from the Northeast direction that located the hustling main road. The open parking has been provided to the Northern direction as well as the southeast direction of the site. The site centers on the Main office building. To the West, a Guesthouse has been provided and along with a cafeteria on the southern side of the side as per the requirement of the project. All around the campus driveway has been given to satisfy fire safety and accessibility norms.

2.7. Site Views

The figures below show the three-dimensional views of the proposed campus along with the proposed buildings.

Figure 24. North view.

Figure 25. South view.

Figure 26. East view.

Figure 27. West view.

The major highlights in these views are the solar chimneys and solariums that are popping out of the buildings playing a major role in passive ventilation of the buildings.

3. PROPOSED DESIGN OF A CAFETERIA

The proposed cafeteria is placed in the southern direction of the site with its main entrance from the Northern direction of the site.

3.1. Floor Plan and the section

The cafeteria predominantly comprises of a required sized dining area, pantry, and kitchen, which are interconnected to each other, with Storage and common toilets respectively.



Figure 28. Cafeteria-floor plan, Figure 29. The section at A-A'.

In the above section of the cafeteria, the kitchen roof can be seen elevated to allow for the design of ventilators at a higher level as compared with the remaining area of the building. The elevated height is provided in the kitchen to put ventilators that allow cross-ventilation, where when the hot air rises it allows to evacuate the hot air through the opposite ventilator of the windward direction. out with.

3.2. Elevations

In the elevation of the cafeteria in the figures below the contour of the site can be seen, where the natural level difference has been taken into consideration for the design of the buildings.


Figure 30. North elevation, Figure 31. South elevation.


Figure 32. East elevation, Figure 33. West elevation.

3.3. Views

The three-dimensional view of the cafeteria shows the elevated roof of the kitchen, designed with a ventilator for natural cross ventilation and exhaustion of the hot air from inside the kitchen to out.


Figure 34. South view, Figure 35. East view.

4. Design of a Guest House

The Guesthouse is placed in the western direction of the site with the main entrance facing the Northern direction of the site.

4.1. Floor Plans

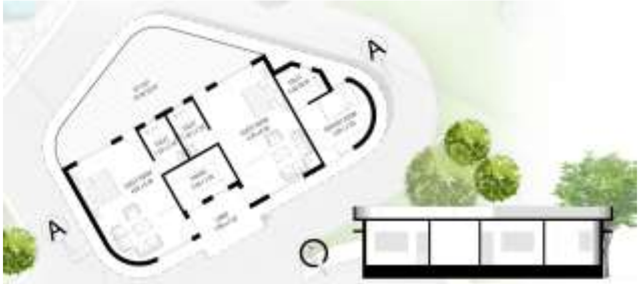

Figure 36. Guest house-floor plan, Figure 37. The section A-A'.

The Guesthouse is designed according to the needs of the project with guest rooms, attached toilets, pantry, and servant room.

The section above the window placement is the matter of highlight which is placed to allow natural cross ventilation for the designed space.

4.2. Elevations

The below figures show the elevations of the guest house which highlights the contour level of the site, which can be seen retained, and the buildings are designed according to the natural site contours.


Figure 38. North elevation, Figure 39. South elevation.


Figure 40. East elevation, Figure 41. West elevation.

4.3. Views

The three-dimensional view of the guest house showing the orientation of the building and surrounding landscape and water features.


Figure 42. West view, Figure 43. South view.

5. Preliminary Data

5.1. Simulation Result

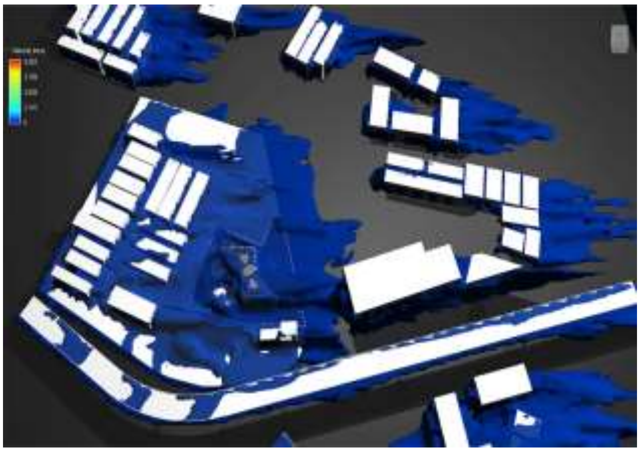

Figure 44. Wind velocity near the building.

The Prevailing wind direction is from the South West, where Natural Wind Speed is 2.00m/s near building facade Wind Speed is 1.00m/s.

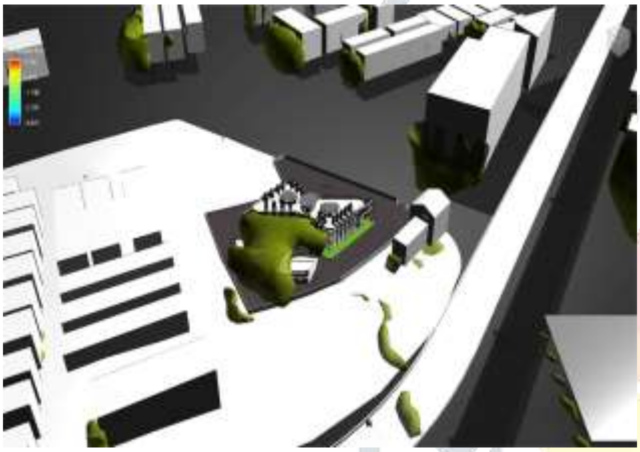

Figure 45. Wind pressure on the building.

The Prevailing wind direction is from the South West, where Natural Wind Speed is 2.0m/s on the Southern side Wind Pressure is +0.63Pa.

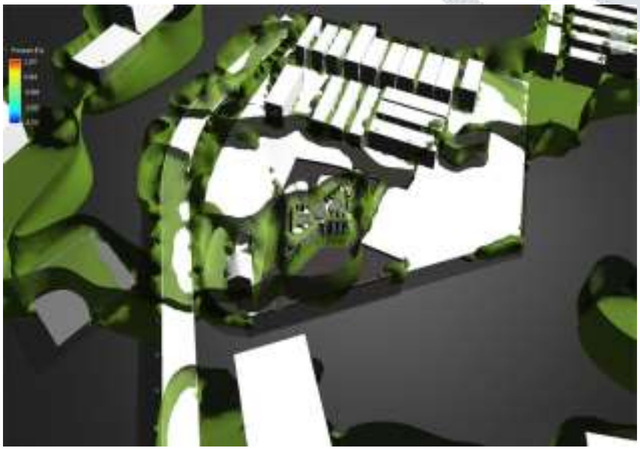

Figure 46. Negative pressure behind the building.

The Prevailing wind direction is from the South West, where Natural Wind Speed is 2.00m/s on the Northern side Wind Pressure is -0.50Pa.

Figure 47. Wind velocity near the building.

The Prevailing wind direction is from North, where Natural Wind Speed is 1.00m/s near building facade Wind Speed is 0.60m/s.

Figure 48. Wind pressure on the building.

The Prevailing wind direction is from the North, where Natural Wind Speed is 1.00m/s on the Northern side Wind Pressure is +0.06Pa.

6. Calculations

The calculations below are all about the required minimum size of the opening for the ventilation

Table 1. Air velocity versus open area.

Velocity	Volume	O Area
2.0 m/s	1 CU.M	0.00040
1.0 m/s	1 CU.M	0.00083
0.5 m/s	1 CU.M	0.60000

Source: B. K. Das

$$OA = \{(Vo/Ts)\ X\ AC\}\ /\ Ve$$

Equation 1

Required open area for Ventilation = {(Volume of the room /1 Hour in Seconds) X Number of Air changes needed} / Air Velocity.

6.1. *The Office Building*

here are two kinds of openings – inlet and outlet. Windows have been designed as inlets, whereas solar chimneys and solariums have been designed as outlets. But adjacent walls of every room have openings facing each other, where each window can act as an inlet and outlet respectively.

Dominantly Solarium and solar chimneys act as outlets all the time. Solarium openings sometimes act as inlet and outlet also as the solariums are oriented in different directions around the building. The openings in the solarium function as inlet or outlet according to the direction of the wind respectively. In the analysis below, a comparative study has been done on the required sizes of the opening and the proposed size provided.

6.1.1. Ground-floor

Figure 49. Ground-floor.

Table 2. Ground-floor room area, volume versus the window, and solar chimney shaft sizes.

GROUND-FLOOR ROOM AREA, VOLUME, WINDOW OPENING, SOLAR CHIMNEY SHAFT SIZES

NAMES	ROOM SIZE			R. OPENING		WINDOW / VENTILATOR			OPENING INTO SOLAR CHIMNEY			NAMES
	AREA (sqm)	HEIGHT (m)	VOLUME (cu.m)	VELOCITY (m/s)	O AREA (sqm)	LENGTH (m)	HEIGHT (m)	AREA (sqm)	DEPTH (m)	WIDTH (m)	AREA (sqm)	
RECEPTION	55.0	3.6	198.0	0.6	0.3	7.2	4.2	30.5	CUT-OUT		18.0	

In the above table room size, height and volume are mentioned according to which the opening size of the windows/ventilator and solar chimney is calculated concerning the velocity of the wind, to satisfy the passive ventilation requirements of the spaces.

6.1.2. First-floor

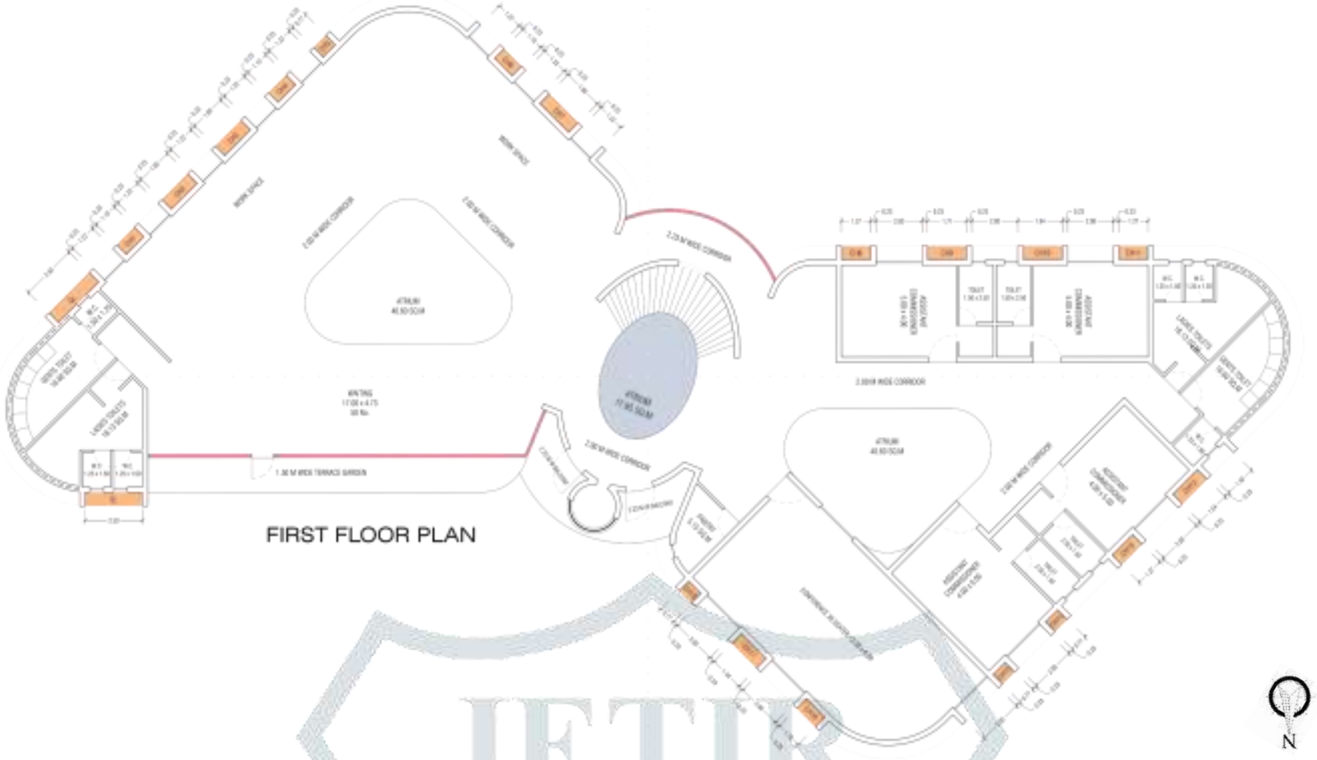

Figure 50. First-floor chimneys.

Table 3. First-floor room area, volume versus the window, and solar chimney shaft sizes.

FIRST-FLOOR ROOM AREA, VOLUME, WINDOW OPENING, SOLAR CHIMNEY SHAFT SIZES

NAMES	ROOM SIZE			R. OPENING		WINDOW / VENTILATOR			OPENING INTO SOLAR CHIMNEY			
	AREA (sqm)	HEIGHT(m)	VOLUME (cum)	VELOCITY(m/s)	O AREA (sqm)	LENGTH(m)	HEIGHT(m)	AREA (sqm)	DEPTH(m)	WIDTH(m)	AREA (sqm)	NAMES
EAST WING												
WAITING	81.8	3.6	294.4	0.6	0.4	6.6	3.0	7.9	CUT-OUT		40.6	
CORRIDORS	56.4	3.6	203.0	0.6	0.3							
GENTS TOILET	16.6	3.6	59.8	0.6	0.1	8.2	0.6	4.9	0.6	2.5	1.5	GL
LOBBY WITH SOLARIUM	37.1	3.6	133.4	1.0	0.1	1.2	1.2	1.5	CUT-OUT		18.0	
WEST WING												
ASSISTANT COMMISSIONER	20.0	3.6	72.0	1.0	0.1	2.0	1.2	2.4	0.6	3.4	2.1	CH8, CH9
ATTACHED TOILET	6.0	3.6	21.6	1.0	0.0	0.6	0.8	0.5				
ASSISTANT COMMISSIONER	20.0	3.6	72.0	1.0	0.1	2.0	1.2	2.4	0.6	3.4	2.1	CH10, CH11
ATTACHED TOILET	6.0	3.6	21.6	1.0	0.0	0.1	0.8	0.0				
ASSISTANT COMMISSIONER	20.0	3.6	72.0	0.6	0.1	2.0	1.2	2.4	0.6	2.8	1.7	CH12, CH13
ATTACHED TOILET	6.0	3.6	21.6	0.6	0.0	0.6	0.8	0.5				
ASSISTANT COMMISSIONER	24.0	3.6	86.4	0.6	0.1	2.0	1.2	2.4	0.6	1.5	0.9	CH14, CH15
ATTACHED TOILET	6.0	3.6	21.6	0.6	0.0	0.6	0.8	0.5				
CONFERENCE ROOM	72.0	3.6	259.2	0.6	0.4	6.0	1.2	7.3	0.6	3.5	2.1	CH16 TO CH18
PANTRY	5.2	3.6	18.5	0.6	0.0	0.6	1.2	0.7				
CORRIDORS	77.4	3.6	278.6	0.6	0.4				CUT-OUT		40.6	
LADIES TOILET	18.1	3.6	65.3	0.6	0.1	4.2	0.6	2.5				
GENTS TOILET	16.6	3.6	59.8	1.0	0.0	8.2	0.6	4.9				
NET TOTAL	489.1		1760.7		2.2			41.0			109.5	

In the above table room size, height and volume are mentioned according to which the opening size of the windows/ventilator and solar chimney is calculated concerning the velocity of the wind, to satisfy the passive ventilation requirements of the spaces.

6.1.3. Second-floor

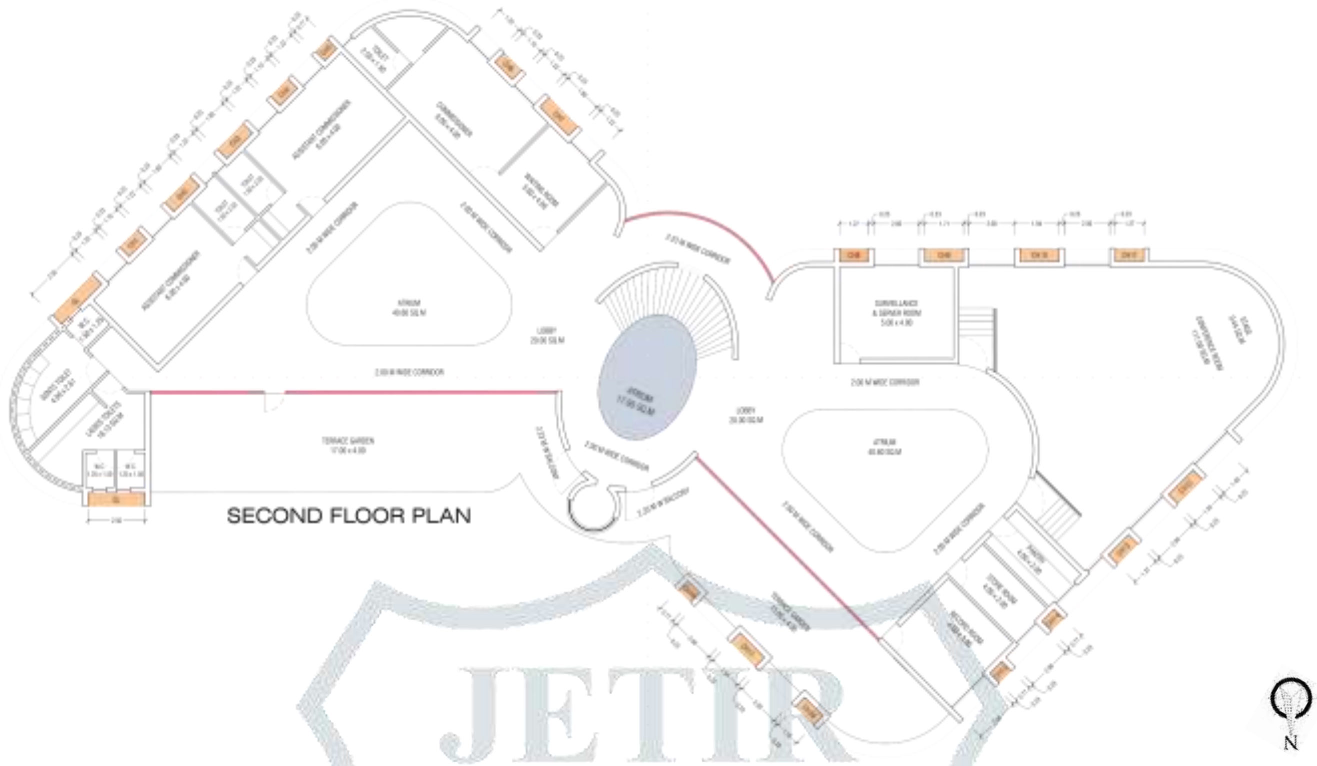

Figure 51. Second-floor chimneys.

Table 4. Second-floor room area, volume versus the window, and solar chimney shaft sizes.

SECOND-FLOOR ROOM AREA, VOLUME, WINDOW OPENING, SOLAR CHIMNEY SHAFT SIZES

NAMES	ROOM SIZE			R. OPENING		WINDOW / VENTILATOR			OPENING INTO SOLAR CHIMNEY			
	AREA (sqm)	HEIGHT(m)	VOLUME (cum)	VELOCITY(m/s)	O AREA (sqm)	LENGTH(m)	HEIGHT(m)	AREA (sqm)	DEPTH(m)	WIDTH(m)	AREA (sqm)	NAMES
EAST WING												
COMMISSIONER	24.0	3.6	86.4	1.0	0.1	2.4	1.2	3.0	0.6	2.7	1.6	CH1, CH2
ATTACHED TOILET	6.0	3.6	21.6	1.0	0.0	0.6	0.9	0.5				
COMMISSIONER	24.0	3.6	86.4	1.0	0.1	2.4	1.2	3.0	0.6	3.5	2.1	CH3 TO CH5
ATTACHED TOILET	6.0	3.6	21.6	1.0	0.0	0.6	0.9	0.5				
COMMISSIONER	24.0	3.6	86.4	1.0	0.1	2.4	1.2	3.0	0.6	2.1	1.3	CH6, CH7
WAITING ROOM	12.0	3.6	43.2	1.0	0.0	1.2	1.2	1.5	0.6	0.9	0.5	CH7
ATTACHED TOILET	6.0	3.6	21.6	1.0	0.0	0.6	0.9	0.5				
CORRIDORS	110.5	3.6	397.9	0.6	0.6	6.6	3.0	7.9	CUT-OUT		40.6	
LADIES TOILET	18.1	3.6	65.3	1.0	0.1	4.2	0.6	2.5	0.6	2.5	1.5	GL
GENTS TOILET	16.6	3.6	59.8	0.6	0.1	8.2	0.6	4.9	0.6	2.5	1.5	GL
LOBBY WITH SOLARIUM	37.1	3.6	133.4	1.0	0.1	1.2	1.2	1.5	CUT-OUT		18.0	
WEST WING												
SURVEILLANCE & SERVER	20.0	3.6	72.0	1.0	0.1	2.0	1.2	2.4	0.6	3.0	1.8	CH8, CH9
CONFERENCE ROOM	118.0	3.6	424.8	1.0	0.4	10.3	1.2	12.6	0.6	6.0	3.6	CH10 TO CH13
PANTRY	8.0	3.6	28.8	0.6	0.0	1.5	1.2	1.8				
STORE ROOM	8.0	3.6	28.8	0.6	0.0	2.0	1.2	2.4	0.6	0.8	0.5	CH14
RECORD ROOM	15.6	3.6	56.2	0.6	0.1	2.0	1.2	2.4	0.6	0.8	0.5	CH15
CORRIDORS	85.5	3.6	307.9	0.6	0.4	4.5	3.0	13.6	CUT-OUT		40.6	
NET TOTAL	539.4		1941.9		2.1			64.3			114.0	

In the above table room size, height and volume are mentioned according to which the opening size of the windows/ventilator and solar chimney is calculated concerning the velocity of the wind, to satisfy the passive ventilation requirements of the spaces.

Opening	Volume (cum)	Velocity (m/s)	R O Area (sqm)	Inlet Area (sqm)	Outlet area (sqm)
Solarium in Lobby Perimeter 25m	258.5	0.6	0.4	5.3	10.0
Solarium in East Wing	584.6	0.6	0.8	40.6	13.1
Solarium in West Wing	584.6	0.6	0.8	40.6	13.1

The above tables are about the solariums which are three-storeyed high. So, if the volume of the solarium is analyzed with the velocity of the wind then the required opening is calculated along with the Inlet and outlet areas. Here the size of the outlet is provided larger than required to enhance adequate ventilation even on no wind (natural wind flow) days, which impacts the ventilation due to less or no wind moment inside the building.

Office Building	Ground	1st	2nd	Total
Wall (sqm)	102.1	545.1	545.1	1192.3
Window (sqm)	48.4	150.5	178.3	377.1
WWR (%)	47%	28%	33%	32%

In the above table, the wall window ratio (in %) has been calculated concerning the area of the wall (in sqm) and the window size (in sqm).

6.1.4. Solar chimney

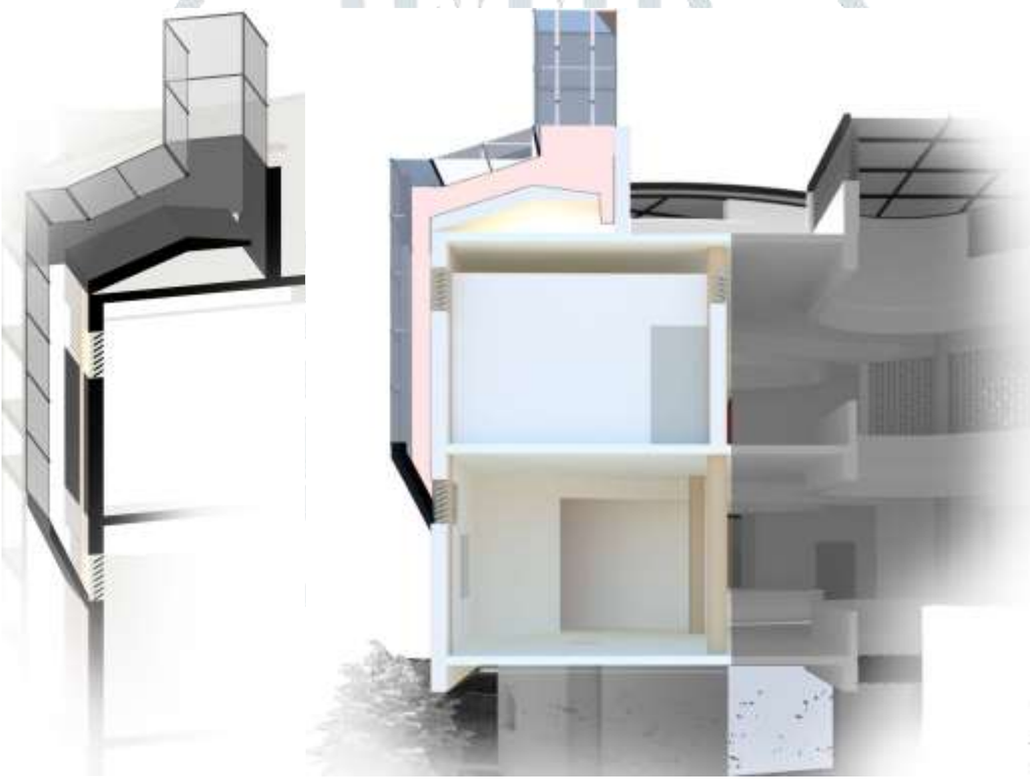

Figure 52. Solar chimney.

Solar chimneys are connected to the first and second floor of the building, where the ventilators are connected to the solariums. Here the solarium outside surface is made out of transparent glass which is 100% SHGC and least U- Value so that the air inside the chimney gets heated up and rises and to go through the chimney duct. Once the hot air gets out, near the ventilator a negative pressure will be created which then will be filled with the cold air from the inlets. The process enhances ventilation inside the room and an adequate amount of air exchange inside the room at a constant cycle and pace naturally.

6.1.5. Solarium

Figure 53 Solarium, Figure 54. Screen wall with the water body.

The figure above shows the passive cooling strategies using solarium structure, screen wall with a water body, and Jali walls. The solarium helps in ventilation and air exchange, with its top part covered with frames with glasses of 50% SHGC to enhance the process of ventilation so that the wind near the glass surface will get heated up and try to escape through ventilators. The solarium has three directional walls with louvered ventilators, so that according to the wind direction one or two will act as air inlet and outlets respectively, but when the wind flow doesn't exist all three will act as air outlets only.

The screen wall with a water body has trellis-like designs with a sprinkler system to sprinkle water. The screen wall directs the air inside the building. When the air moves horizontally through the screen wall, it passes through the sprinkling water, which makes the air reduce the temperature and cold air gets circulated throughout the building.

Figure 54. Jali wall.

Jali-walls have also been provided with 40% of the opening area to provide a venturi effect to enhance the reduction in the temperature of the outside wind coming inside the building.

6.2. The Cafeteria

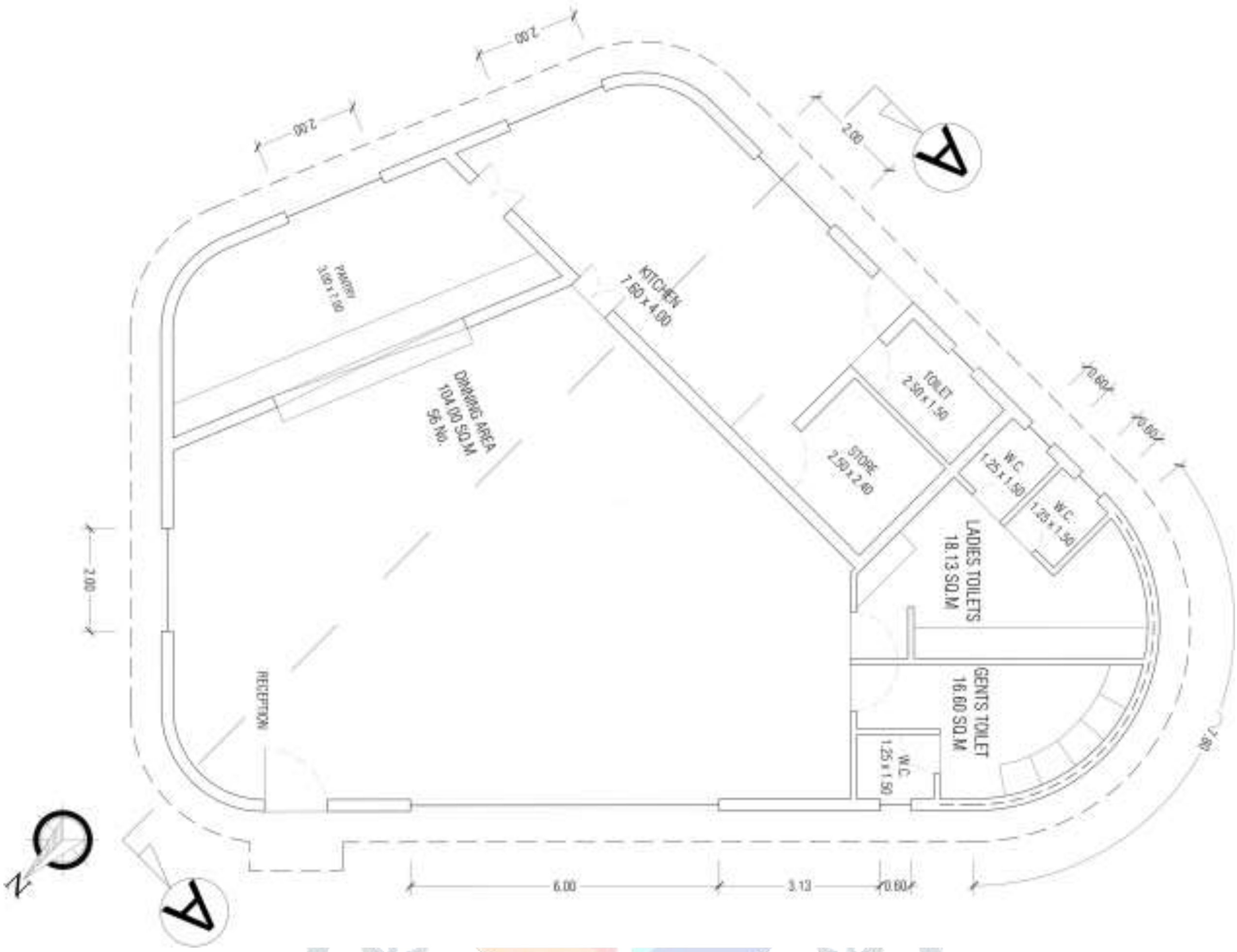

Figure 55. Cafeteria-floor plan.

Cante	Area
Wall	205.9
Window	49.5
WWR	24%

Table 5. Cafeteria room area, volume versus window, and counter window sizes.

ROOM AREA, VOLUME VERSUS WINDOW AND COUNTER WINDOW SIZES

NAMES	ROOM SIZE			R. OPENING		WINDOW / VENTILATOR			COUNTER WINDOW		
	AREA (sqm)	HEIGHT(m)	VOLUME (cum)	VELOCITY(m/s)	O AREA (sqm)	LENGTH(m)	HEIGHT(m)	AREA (sqm)	DEPTH(m)	WIDTH(m)	AREA (sqm)
DINING	104.0	3.0	312.0	0.6	0.4	6.0	1.2	7.3	2.0	1.2	2.4
PANTRY	21.0	3.0	63.0	1.0	0.1	2.0	0.9	1.8			
KITCHEN	30.4	4.5	136.8	1.0	0.4	4.0	1.2	4.9	20.5	1.2	25.0
STORE	6.0	3.0	18.0								
TOILET	3.8	3.0	11.3	1.0	0.0	0.6	0.9	0.5			
LADIES TOILET	18.1	3.0	54.4	1.0	0.0	4.2	0.6	2.5			
GENTS TOILET	16.6	3.0	49.8	0.6	0.1	8.2	0.6	4.9			
NET TOTAL	199.9		645.2		1.0			22.0			27.5

In the above table room size, height and volume are mentioned according to which the opening size of the windows/ventilator and solar chimney is calculated concerning the velocity of the wind, to satisfy the passive ventilation requirements of the spaces.

6.3. The Guest House

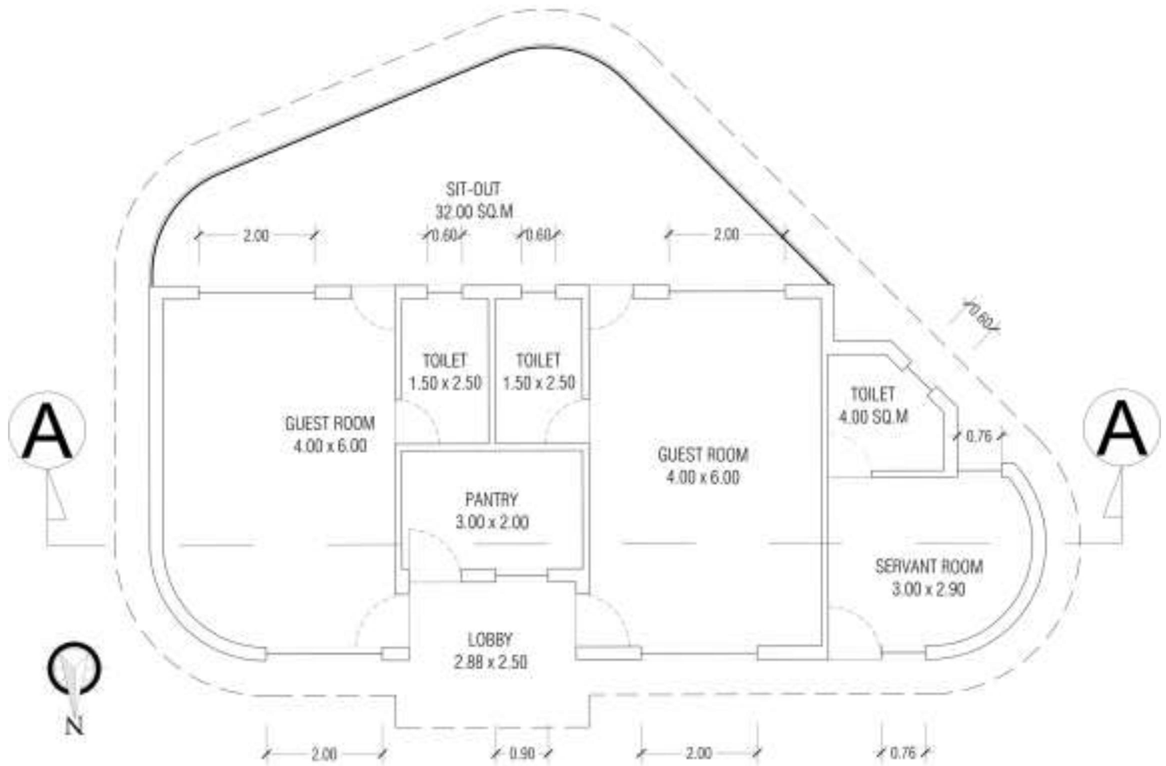

Figure 56. Guest-floor plan.

Guest	Area
Wall	119.4
Window	13.0
WWR	11%

Table 6. Guesthouse room area, volume versus window, and counter window sizes.

ROOM AREA, VOLUME VERSUS WINDOW AND COUNTER WINDOW SIZES

NAMES	ROOM SIZE			R. OPENING		WINDOW / VENTILATOR			COUNTER WINDOW		
	AREA (sqm)	HEIGHT(m)	VOLUME (cum)	VELOCITY(m/s)	O AREA (sqm)	LENGTH(m)	HEIGHT(m)	AREA (sqm)	DEPTH(m)	WIDTH(m)	AREA (sqm)
EAST BED ROOM	24.0	3.0	72.0	0.6	0.1	2.0	1.2	2.4	2.0	1.2	2.4
TOILET	3.8	3.0	11.3	0.6	0.0	0.6	0.8	0.5			
TOILET	3.8	3.0	11.3	0.6	0.0	0.6	0.8	0.5			
EAST BED ROOM	24.0	3.0	72.0	0.6	0.1	2.0	1.2	2.4	2.0	1.2	2.4
SERVANT ROOM	8.7	3.0	26.1	0.6	0.0	0.8	1.2	0.9	0.8	1.2	0.9
TOILET	4.0	3.0	12.0	0.6	0.0	0.6	0.8	0.5			
SIT-OUT	32.0	3.0	96.0	0.6	0.1						
NET TOTAL	100.2		300.6		0.4			7.2			5.8

In the above table room size, height and volume are mentioned according to which the opening size of the windows/ventilator and solar chimney is calculated concerning the velocity of the wind, to satisfy the passive ventilation requirements of the spaces.

7. ENERGY SIMULATIONS

7.1. Site Data

7.1.1. Site data run period

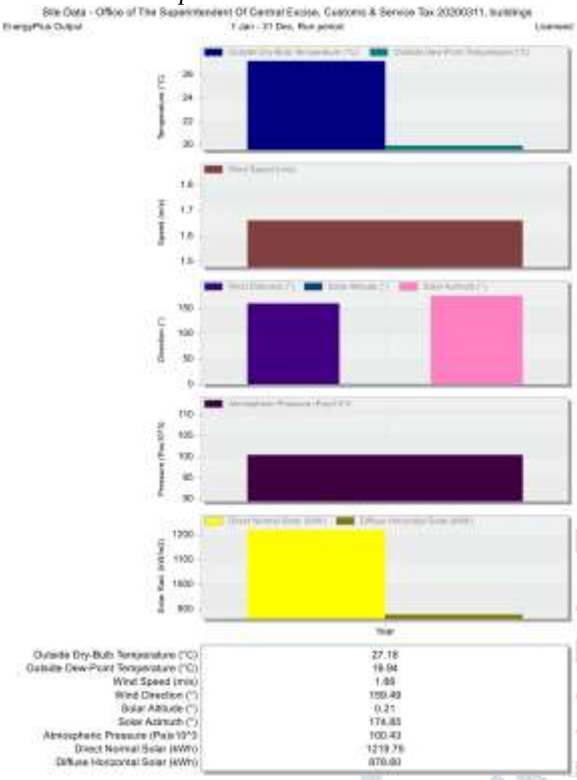

Figure 57. Site data run period.

The above figure shows the run period, which means the time of the office period has been considered i.e., from 9 am to 6 pm. In the run period, the average temperature, speed of the wind, the direction of the wind, wind pressure, and the solar radiation of an entire year has been analysed.

7.1.2. Site data monthly

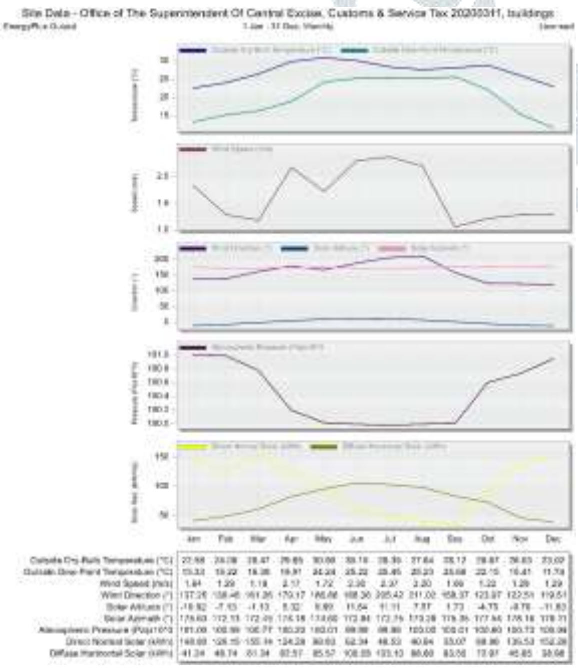

Figure 58. Site data monthly.

The above figure shows the run period, which means the time of the office period has been considered i.e., from 9 am to 6 pm. In the run period, the average temperature, speed of the wind, the direction of the wind, wind pressure, and the solar radiation of each month has been analysed.

In the above analysis, it can be observed that the pressure in the atmosphere reduces in the hotter months of the year, i.e., in summer solstices the wind pressure is less and in the winter solstices the wind pressure is high. Solar radiation is observed to be direct normal in summer solstice is less, horizontal diffuse solar radiation is high. In winter solstices, the direct normal solar radiation is high. Hence according to these analyses of the particular zone considered for the proposed project the strategies have been implemented.

8. THE OFFICE BUILDING WITH NATURAL VENTILATION AND INFILTRATION

8.1. Settings

Figure 59. Settings for natural ventilation and infiltration.

Figure 60. Simulation model.

8.2. The Office building CFD & Air Temperatures (Wind from North)

The Prevailing wind direction is from the North, where Natural Wind Speed is 1.00m/s near the building facade Wind Speed is 0.60m/s, average outdoor temperature 24ºC.

Ground-floor CFD result at 1.0m height

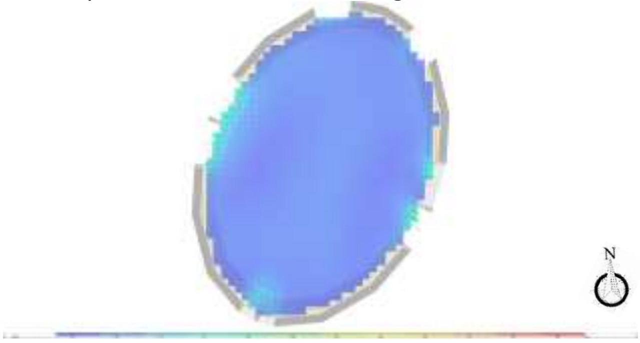

Figure 61. Velocity range (0-0.70 m/s).

Ground-floor Air temperature at 1.0m height

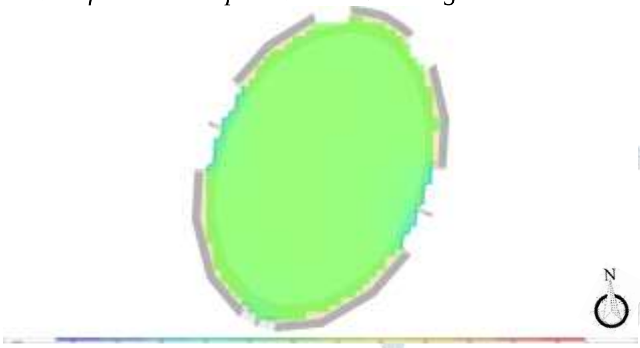

Figure 62. Air temperature range (24ºC)

First-floor CFD result at 1.0m height

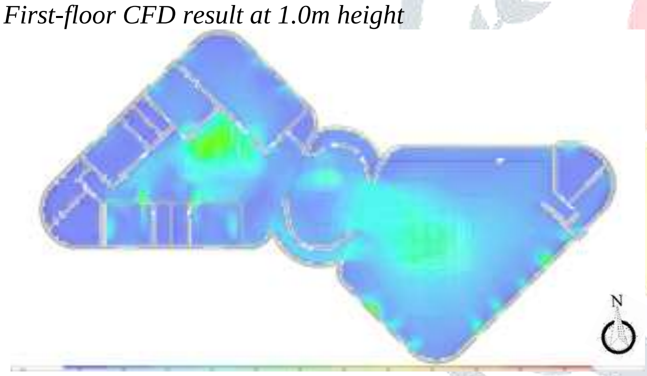

Figure 63. Velocity range (0.10-0.70 m/s).

First-floor Air temperature at 1.0m height

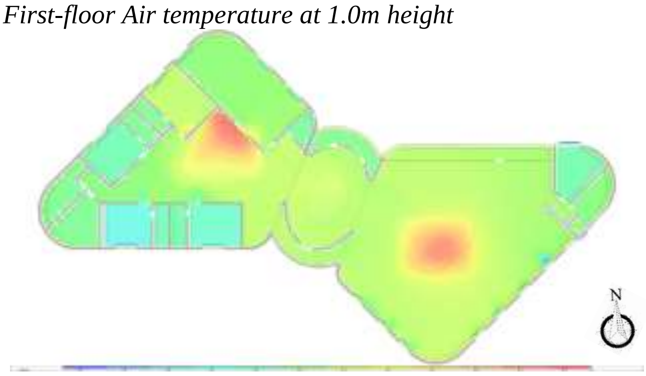

Figure 64. Air temperature range (20ºC-30ºC)

Here as the solarium is placed at the west and east wings their temperature is high at the centre of the building.

Second-floor CFD result at 1.0m height

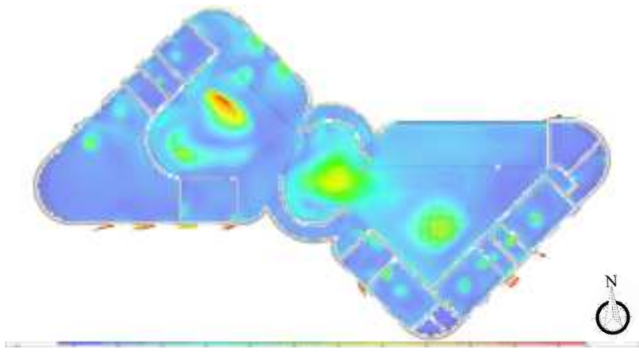

Figure 65. Velocity range (0.10-0.70 m/s).

Second-floor Air temperature at 1.0m height

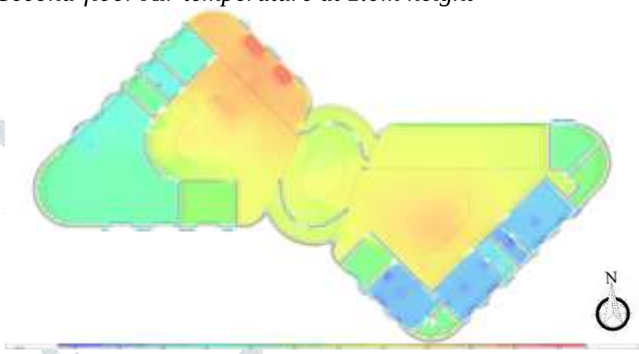

Figure 66. Air temperature range (20ºC-30ºC)

Terrace-floor CFD result at 0.5m height

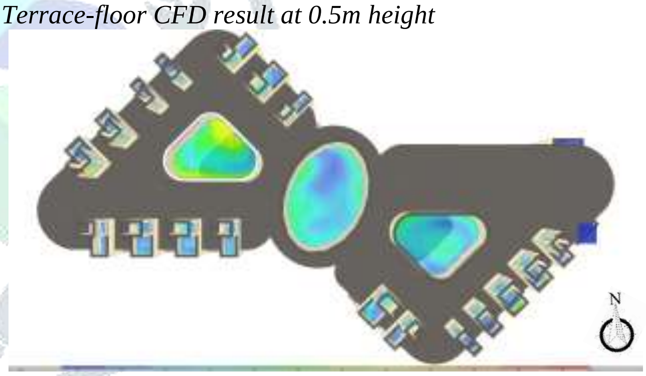

Figure 67. Velocity range (0.10-0.70 m/s).

Terrace-floor Air temperature at 0.5m height

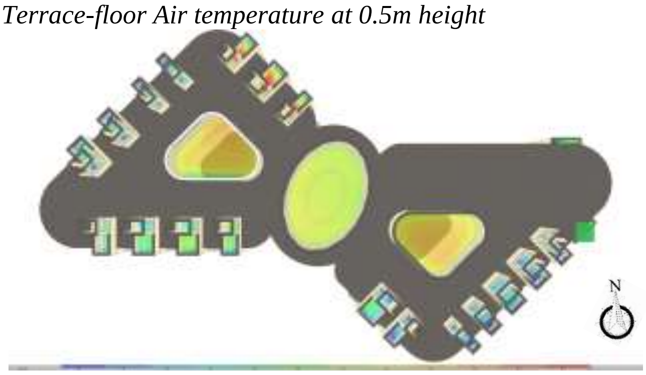

Figure 68. Air temperature range (20ºC-30ºC)

CFD The sectional views

The figures below show the sectional views of the building with wind movement and temperature variation inside the building.

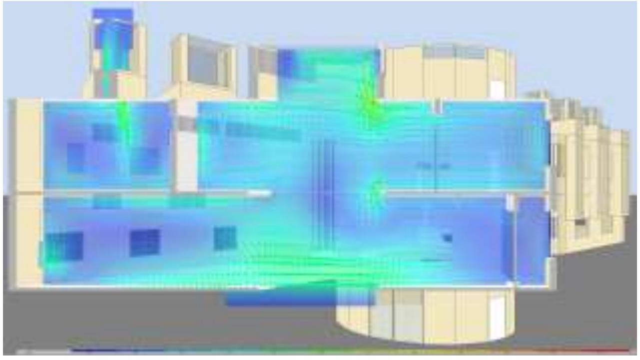

Figure 69. The section through East solarium showing Velocity.

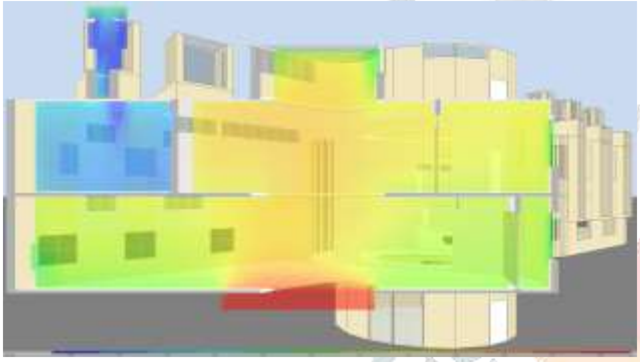

Figure 70. The section through East solarium showing temperature.

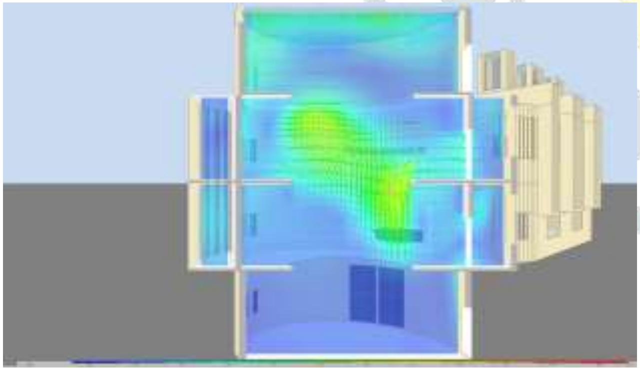

Figure 71. The section through central solarium showing Velocity.

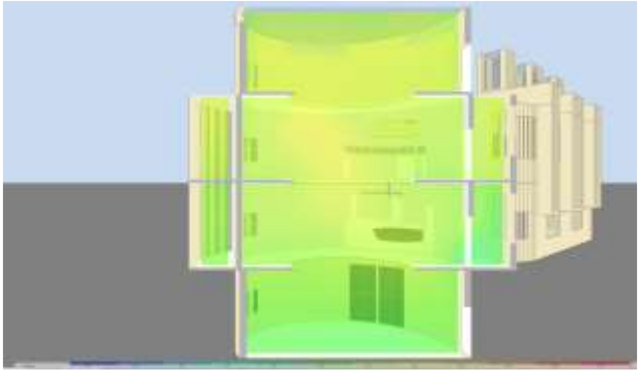

Figure 72. The section through central solarium showing temperature.

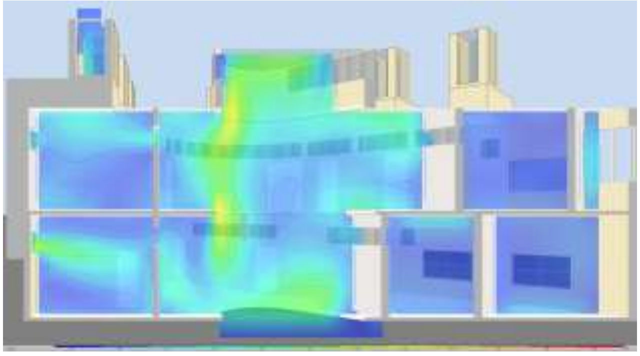

Figure 73. The section through West solarium showing Velocity.

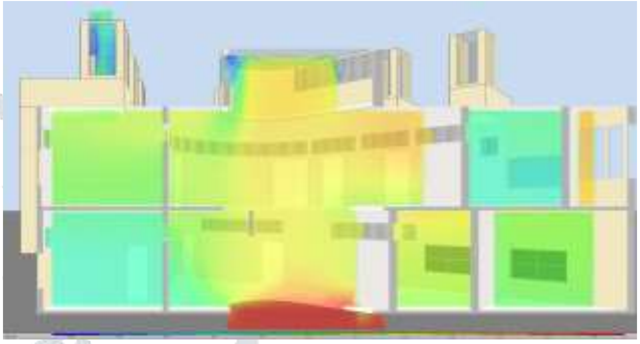

Figure 74. The section through West solarium showing temperature.

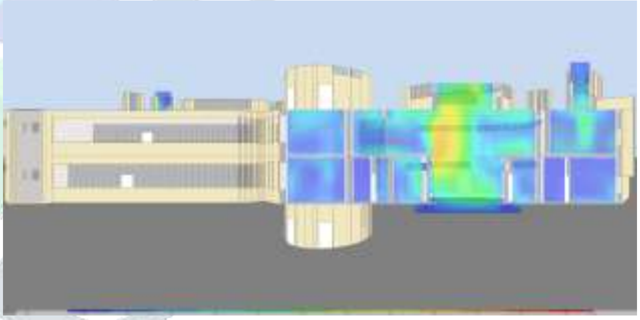

Figure 75. The section through West solarium showing Velocity.

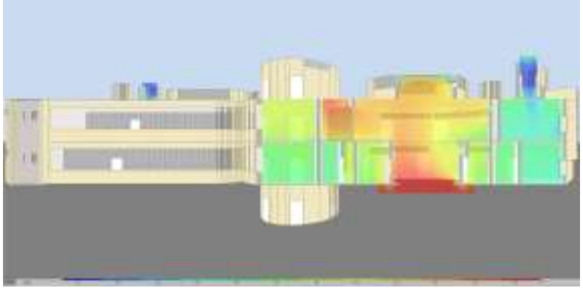

Figure 76. The section through West solarium showing temperature.

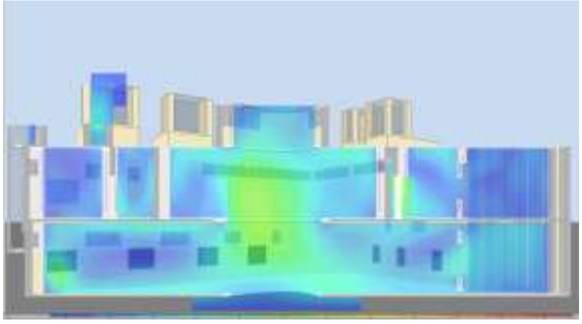

Figure 77. The section through East solarium showing Velocity.

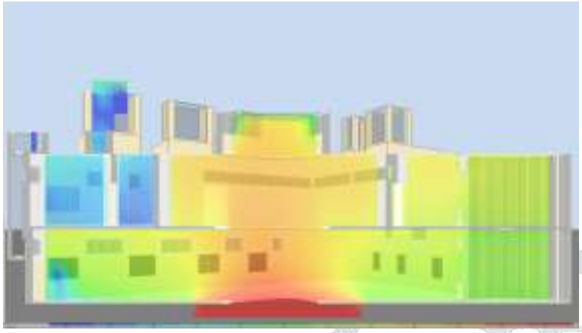

Figure 78. The section through East solarium showing temperature.

8.3. Office building CFD & Air Temperatures (Wind from South-West)

The Prevailing wind direction is from the South West, where Natural Wind Speed is 2.00m/s near the building facade Wind Speed is 1.00m/s, outdoor average temperature 35ºC.

Ground-floor CFD result at 1.0m height

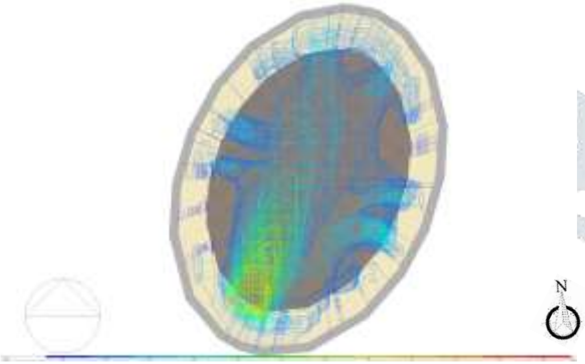

Figure 79. Velocity range (0-3.0 m/s).

Ground-floor Air temperature at 1.0m height

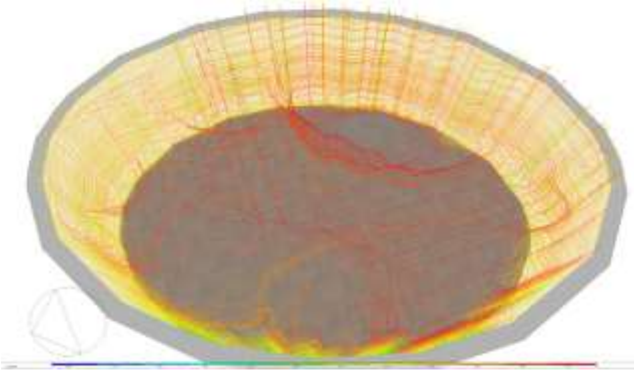

Figure 80. Air temperature range (20ºC-30ºC)

First-floor CFD result at 1.0m height

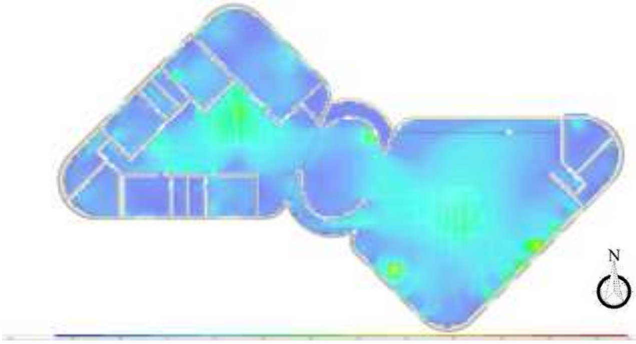

Figure 81. Velocity range (0.10-0.70 m/s).

First-floor Air temperature at 1.0m height

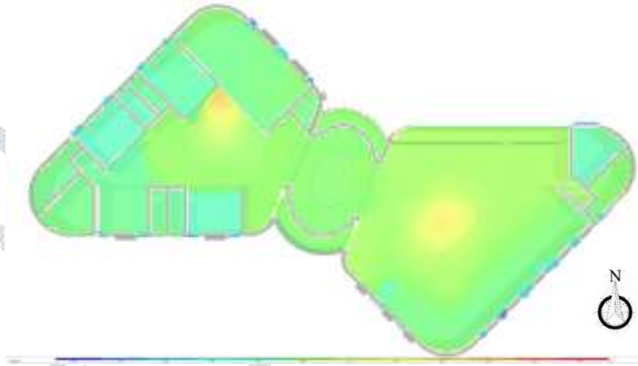

Figure 82. Air temperature range (20ºC-30ºC)

Second-floor CFD result at 1.0m height

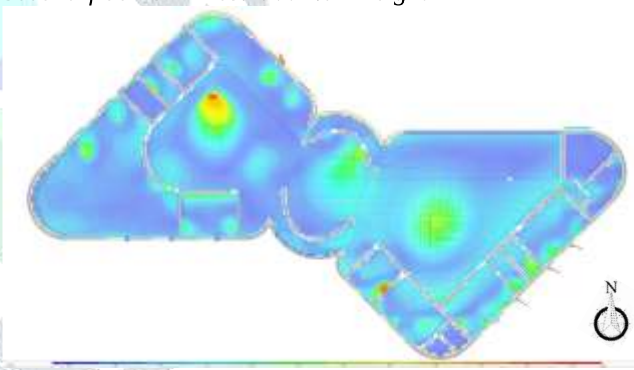

Figure 83. Velocity range (0.10-0.70 m/s).

Second-floor Air temperature at 1.0m height

Figure 84. Air temperature range (20ºC-30ºC)

Terrace-floor CFD result at 0.5m height

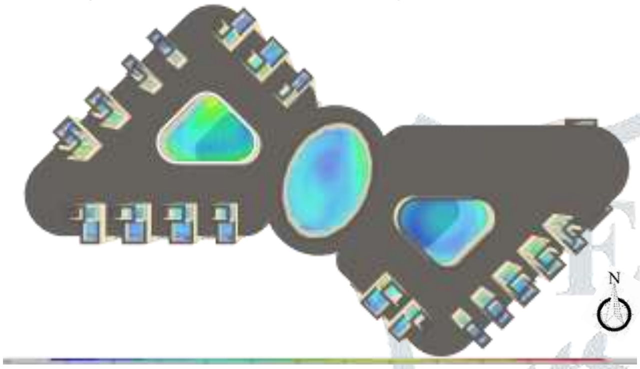

Figure 85. Velocity range (0.10-0.70 m/s).

Terrace-floor Air temperature at 0.5m height

Figure 86. Air temperature range (20ºC-30ºC)

CFD sectional views

The figures below show the sectional views of the building with wind movement and temperature variation inside the building.

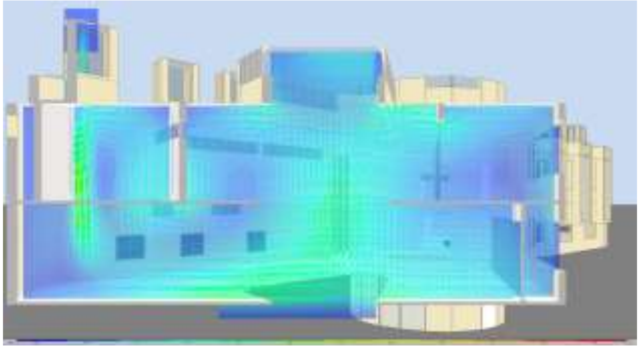

Figure 87. The section through East solarium showing Velocity.

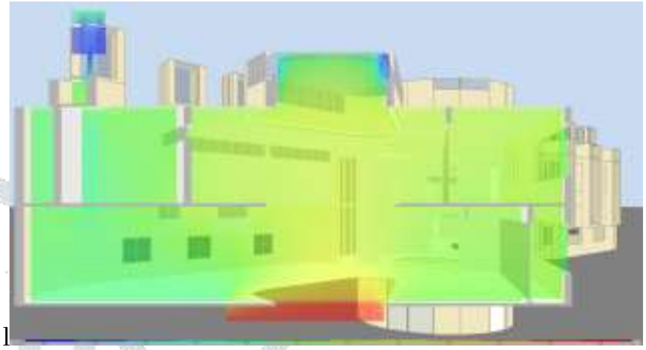

Figure 88. The section through East solarium showing temperature.

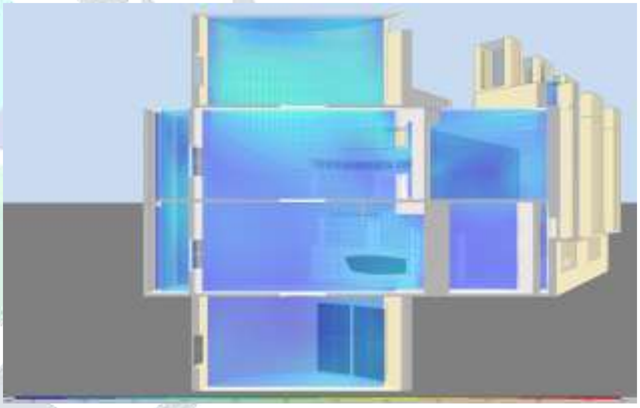

Figure 89. The section through central solarium showing Velocity.

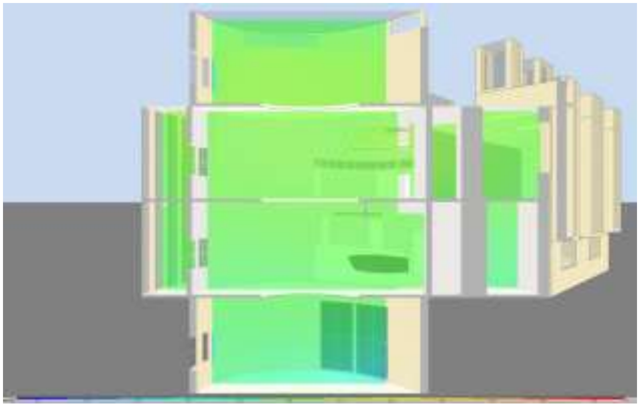

Figure 90. The section through central solarium showing temperature.

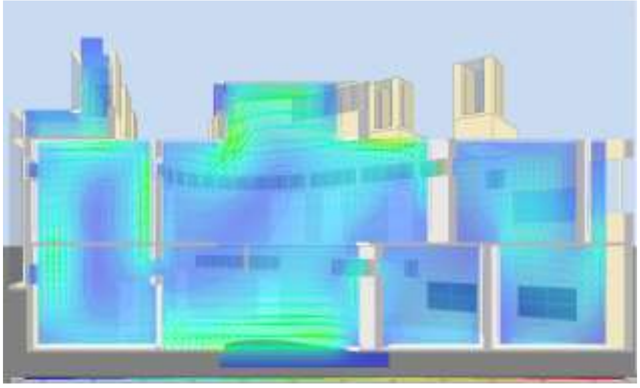

Figure 91. The section through West solarium showing Velocity.

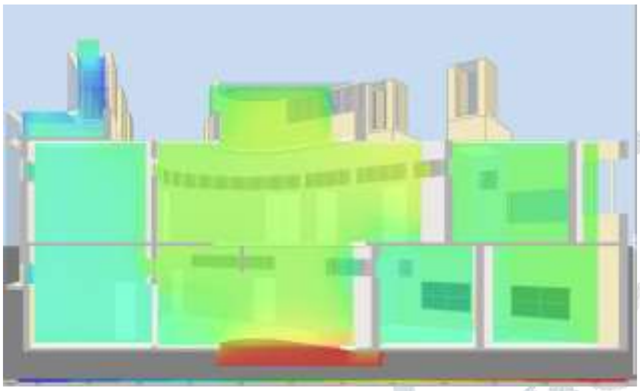

Figure 92. The section through West solarium showing temperature.

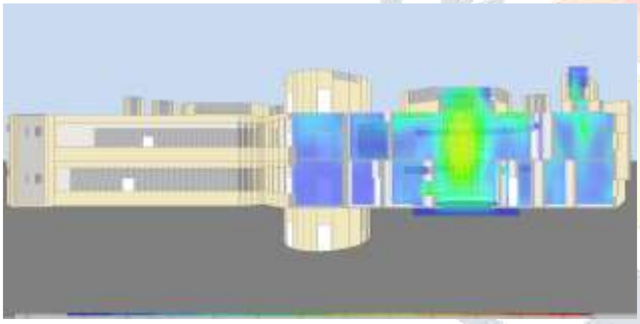

Figure 93. The section through West solarium showing Velocity.

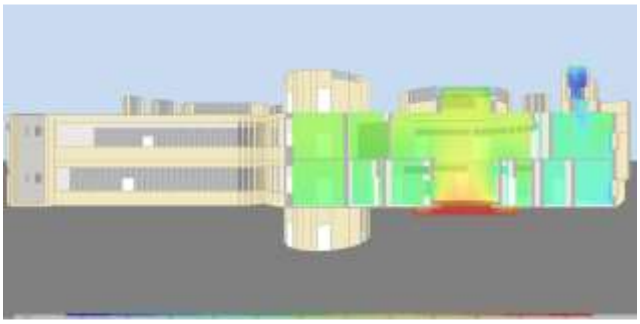

Figure 94. The section through West solarium showing temperature.

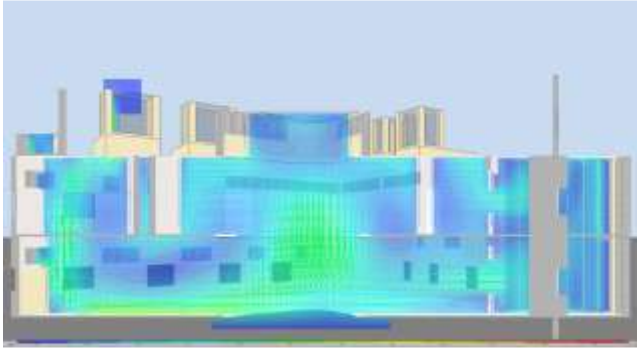

Figure 95. The section through East solarium showing Velocity.

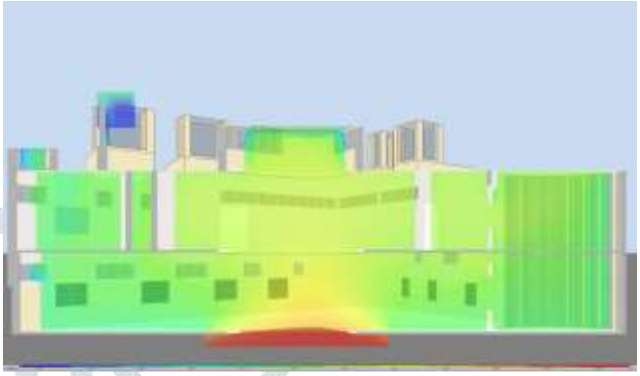

Figure 96. The section through East solarium showing temperature.

9. The Office Building With HVAC

9.1. Settings

Figure 97. Settings for HVAC.

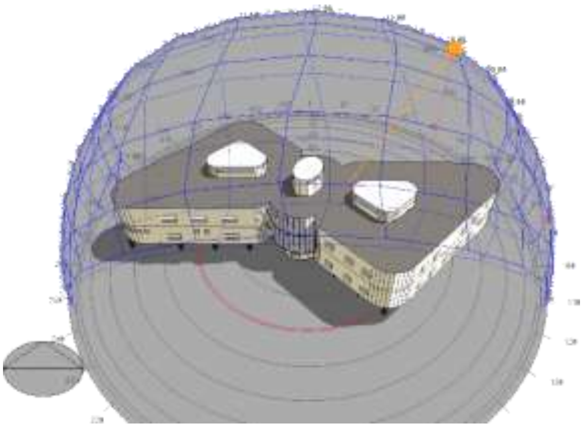

Figure 98. Simulation model.

10. The Office Building Performance Comparison

10.1. Air Temperature

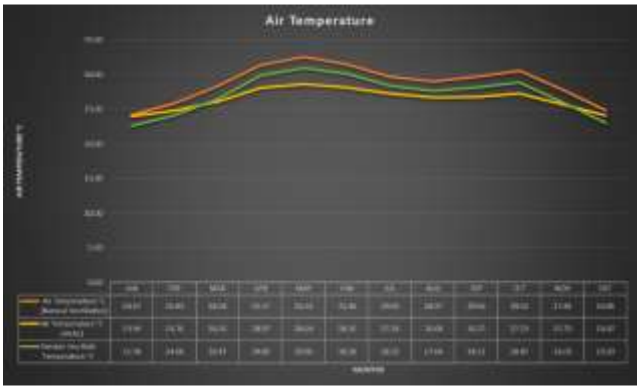

Figure 99. Monthly average air temperature.

Proposed passive ventilation strategies are significantly balancing the air temperature between 24°C – 32°C throughout the year.

10.2. Ventilation

Figure 100 Monthly average air changes per hour.

Proposed passive ventilation strategies are providing more than enough average air changes of 70 throughout the year as air changes between (48 – 93).

10.3. Fuel totals

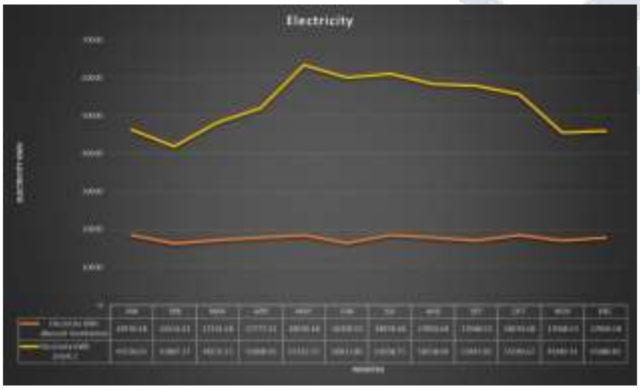

Figure 101. Monthly average fuel totals.

The total energy consumption in a natural ventilated building is **33%** of the actively ventilated building. 67% of energy consumption can be reduced annually.

10.4. CO_2 Emissions

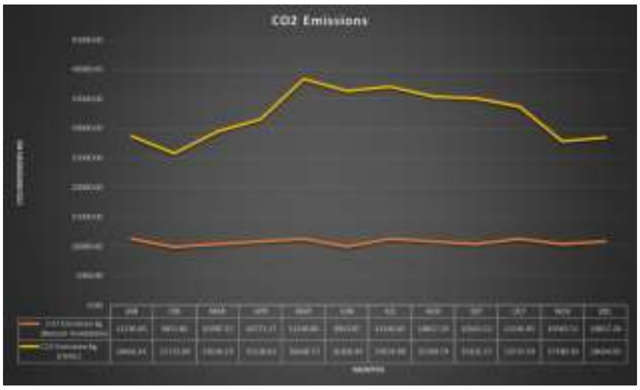

Figure 102. Monthly average CO2 emissions.

The total CO_2 Emissions in the natural ventilated building is **33%** (19056.11 kWh) of actively ventilated building. 67% of CO2 Emissions can be prevented annually.

11. The Cafeteria with Natural Ventilation and Infiltration

11.1. Settings

Figure 103. Settings for natural ventilation and infiltration.

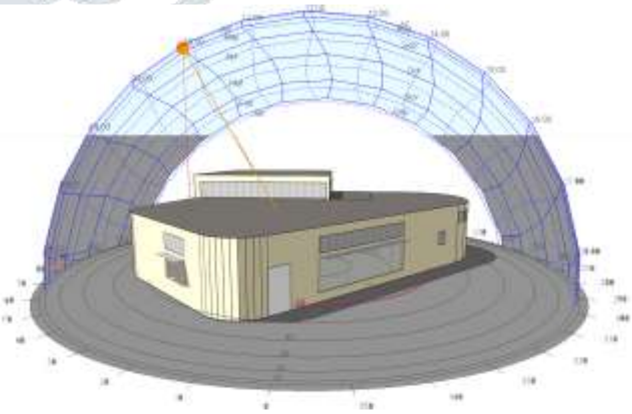

Figure 104. Simulation model.

11.2. The Cafeteria CFD & Air Temperatures (Wind from North)

The Prevailing wind direction is from the North, where Natural Wind Speed is 1.00m/s near the building facade Wind Speed is 0.60m/s, average outdoor temperature 30ºC.

Ground-floor CFD result at 1.0m height

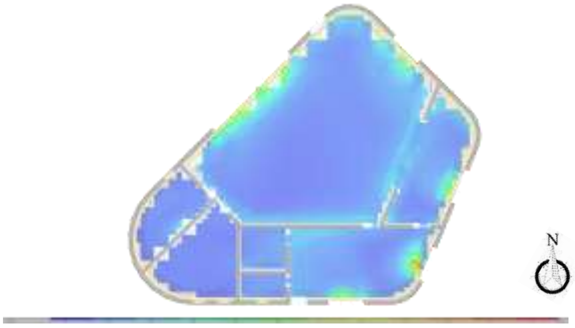

Figure 105. Velocity range (0-0.30 m/s).

Ground-floor Air temperature at 1.0m height

Figure 106. Air temperature range (20ºC-30ºC)

Elevated kitchen roof CFD result at 3.5m height

Figure 107. Velocity range (0.10-0.0 m/s).

Elevated kitchen roof Air temperature at 3.5m height

Figure 108. Air temperature range (20ºC-30ºC)

CFD The sectional views

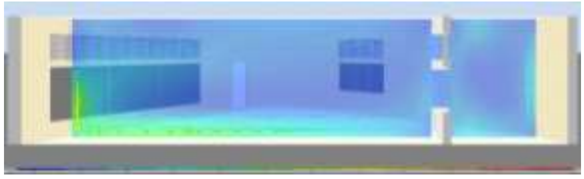

Figure 109. The section through Dining, Pantry showing Velocity.

Figure 110. The section through Dining, Pantry showing temperature.

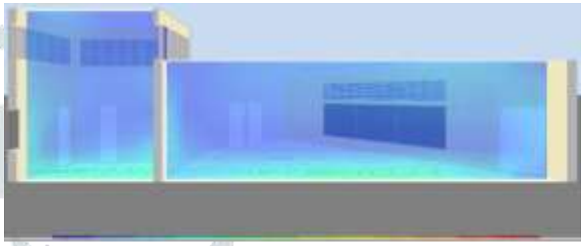

Figure 111. The section through Dining, Kitchen showing Velocity.

Figure 112. The section through Dining, Kitchen showing temperature.

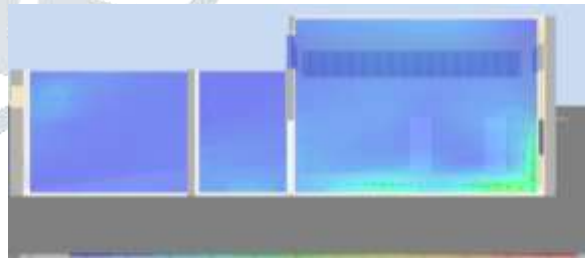

Figure 113. The section through Toilet, Kitchen showing Velocity.

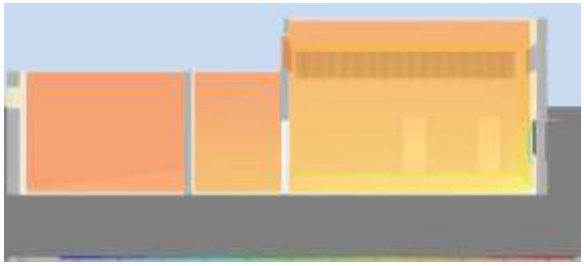

Figure 114. The section through Toilet, Kitchen showing temperature.

11.3. The Cafeteria CFD & Air Temperatures (Wind from S-W)

The Prevailing wind direction is from the South West, where Natural Wind Speed is 2.00m/s near the building facade Wind Speed is 1.00m/s, outdoor average temperature 35ºC.

Ground-floor CFD result at 1.5m height

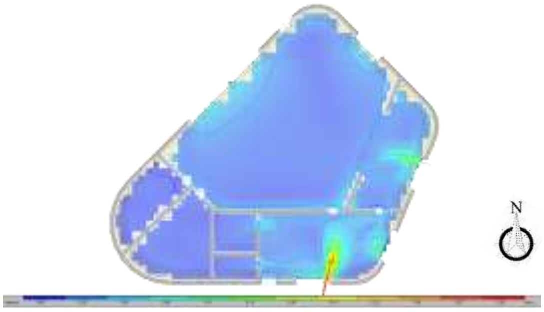

Figure 115. Velocity range (0-0.3 m/s).

Ground-floor Air temperature at 1.5m height

Figure 116. Air temperature range (20ºC-35ºC)

Elevated kitchen roof CFD result at .m height

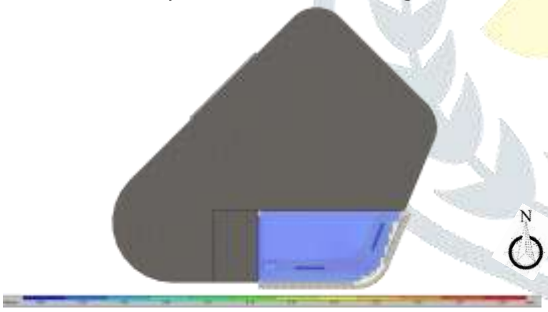

Figure 117. Velocity range (0.10-0.70 m/s).

Elevated kitchen roof Air temperature at 0.5m height

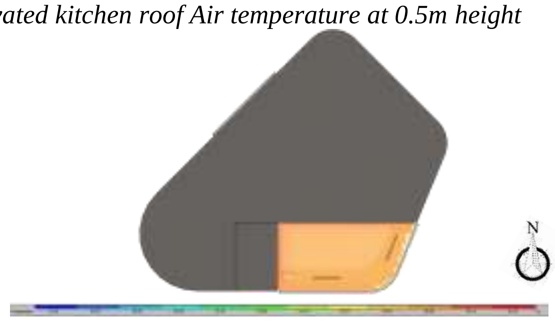

Figure 118. Air temperature range (20ºC-35ºC)

CFD The sectional views

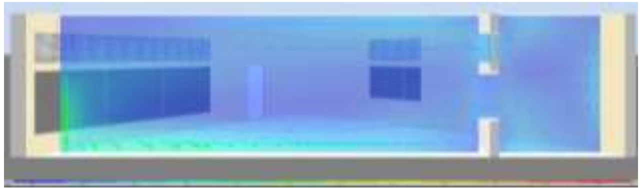

Figure 119. The section through Dining, Pantry showing Velocity.

Figure 120. The section through Dining, Pantry showing temperature.

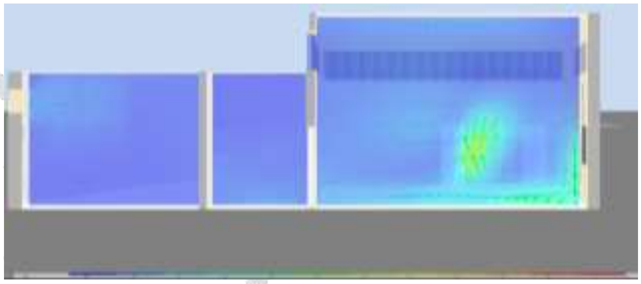

Figure 121. The section through Dining, Kitchen showing Velocity.

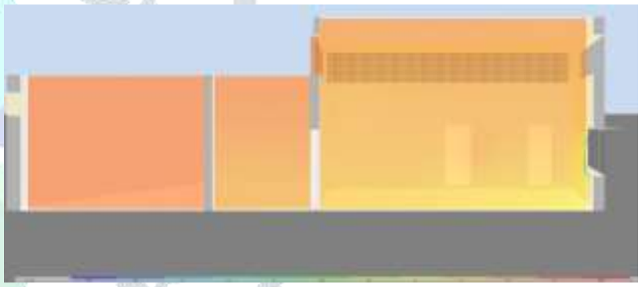

Figure 122. The section through Dining, Kitchen showing temperature.

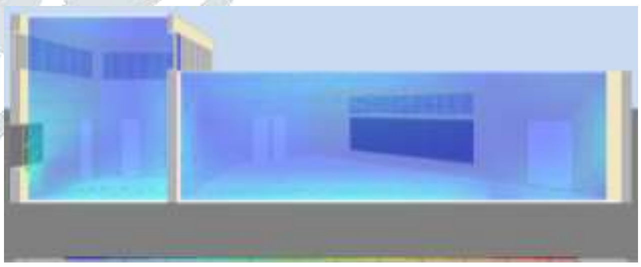

Figure 123. The section through Toilet, Kitchen showing Velocity.

Figure 124. The section through Toilet, Kitchen showing temperature.

12. The Cafeteria With DX

12.1. Settings

Figure 125. Settings for DX.

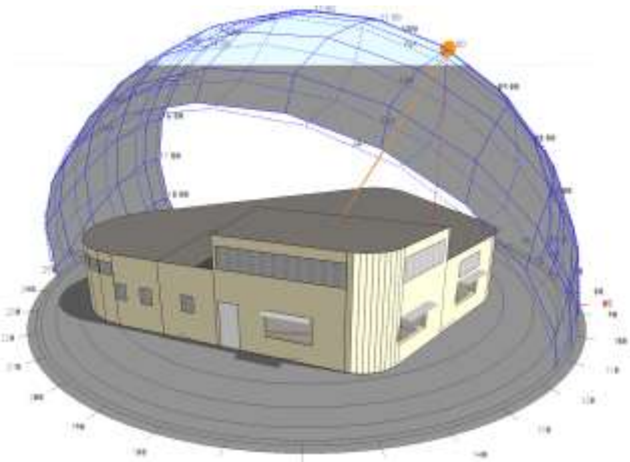

Figure 126. Simulation model.

13. The Cafeteria Performance Comparison

13.1. Air Temperature

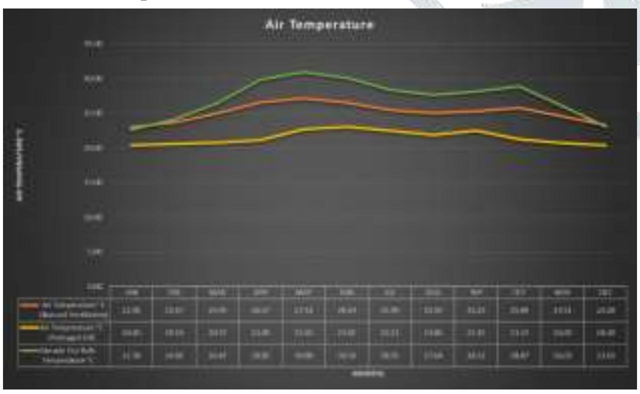

Figure 127. Monthly average air temperature.

Proposed passive ventilation strategies are significantly balancing the average air temperature of 25°C throughout the year as a temperature difference between 22°C- 27°C.

13.2. Ventilation

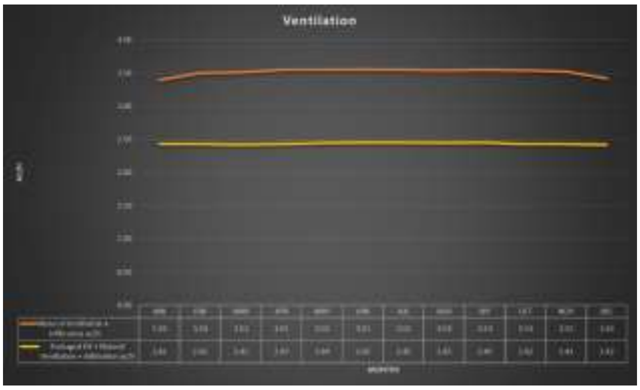

Figure 128. Monthly average air changes per hour.

Proposed passive ventilation strategies are providing more than enough average air changes of 3.5 throughout the year as air changes between (3.39 – 3.54).

13.3. Fuel totals

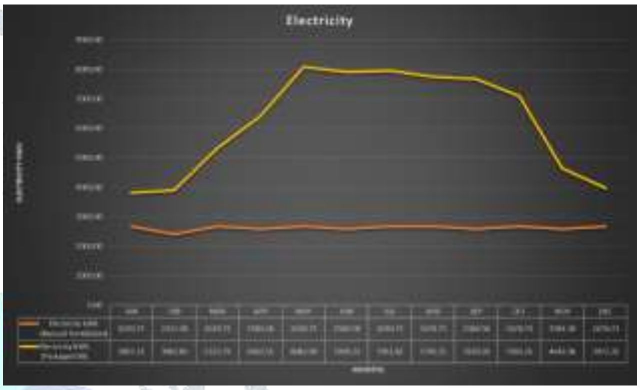

Figure 129. Monthly average fuel totals.

The total energy consumption in a natural ventilated building is **42%** of the actively ventilated building. 58% of energy consumption can be reduced annually.

13.4. CO_2 Emissions

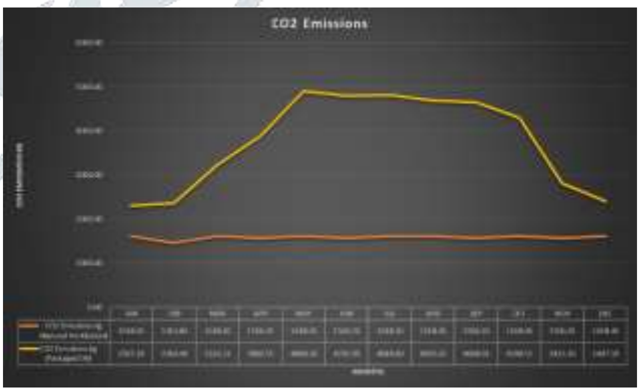

Figure 130. Monthly average CO_2 emissions.

The total CO_2 Emissions in the natural ventilated building is **42%** of the actively ventilated building. 58% of CO2 Emissions can be prevented annually.

14. The Guest House with Natural Ventilation and Infiltration

14.1. Settings

Figure 131. Settings for natural ventilation and infiltration.

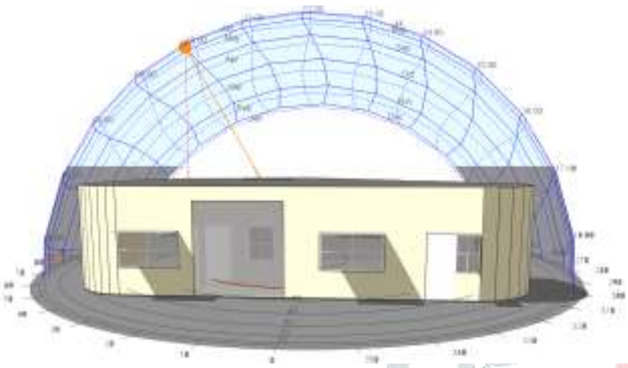

Figure 132. Simulation model.

14.2. The Guest House CFD & Air Temperatures (Wind from North)

The Prevailing wind direction is from the North, where Natural Wind Speed is 1.00m/s near the building facade Wind Speed is 0.60m/s, average outdoor temperature 30ºC.

Ground-floor CFD result at 1.5m height

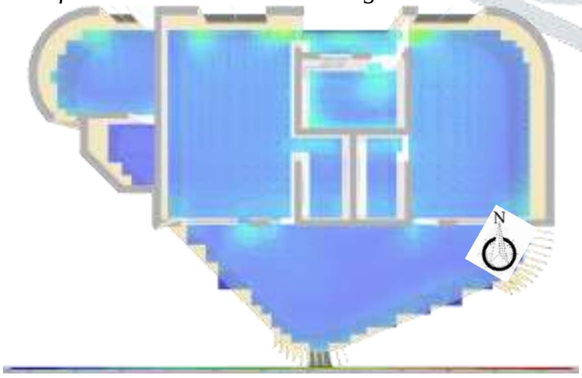

Figure 133. Velocity range (0-0.50 m/s).

Ground-floor Air temperature at 1.5m height

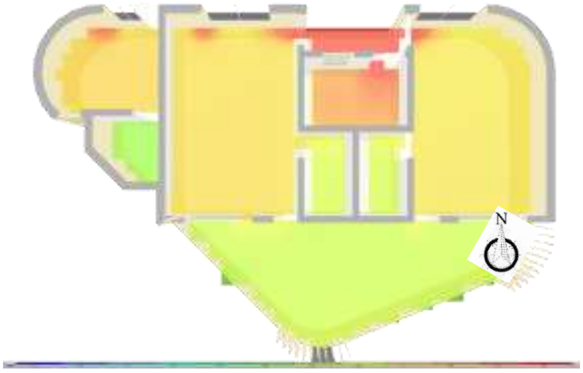

Figure 134. Air temperature range (19ºC-31ºC)

CFD The sectional views

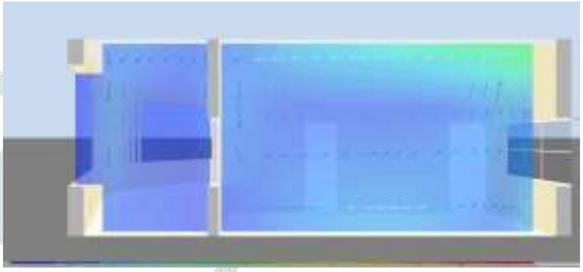

Figure 135. The section through the Bedroom showing Velocity.

Figure 136. The section through the Bedroom showing temperature.

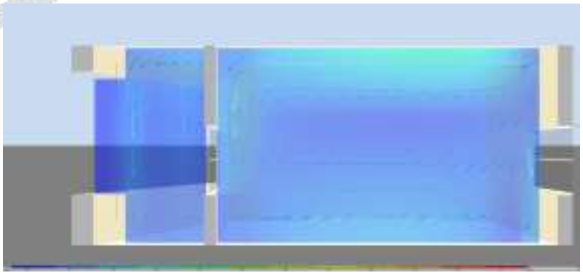

Figure 137. The section through the Bedroom showing Velocity.

14.3. The Guest House CFD & Air Temperatures (Wind from South-West)

The Prevailing wind direction is from the South West, where Natural Wind Speed is 2.00m/s near the building facade Wind Speed is 1.00m/s, outdoor average temperature 35ºC.

Ground-floor CFD result at 1.5m height

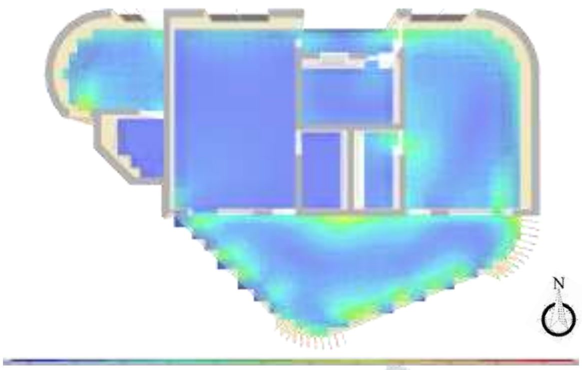

Figure 138. Velocity range (0-0.50 m/s).

Ground-floor Air temperature at 1.5m height

Figure 139. Air temperature range (25ºC-34ºC)

CFD The sectional views

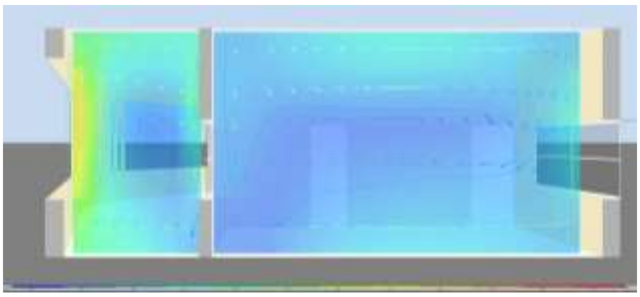

Figure 140. The section through the Bedroom showing Velocity.

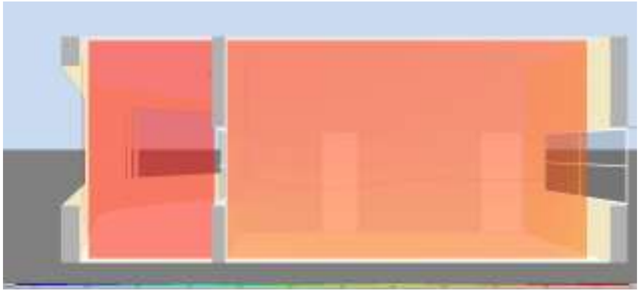

Figure 141. The section through the Bedroom showing temperature.

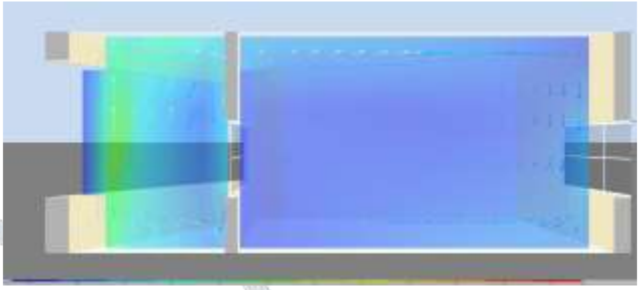

Figure 142. The section through the Bedroom showing Velocity.

15. The Guest House With DX

15.1. Settings

Figure 143. Settings for DX

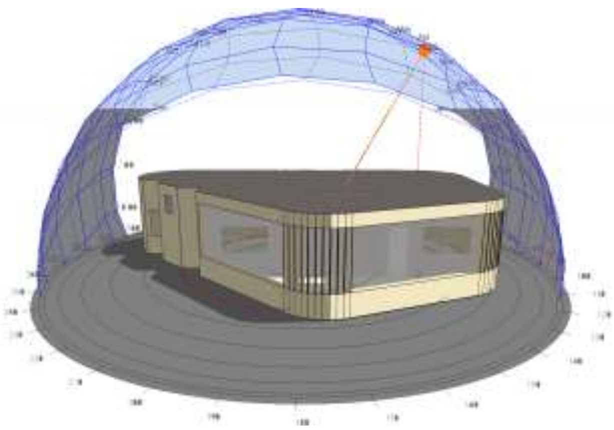

Figure 144. Simulation model.

16. The Guest House Performance Comparison

16.1. Air Temperature

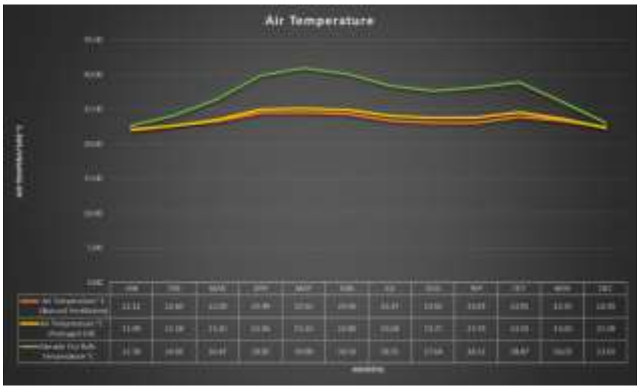

Figure 145. Monthly average air temperature.

Proposed passive ventilation strategies are significantly balancing the average air temperature of 25°C throughout the year as a temperature difference between 22°C to 27°C.

16.2. Ventilation

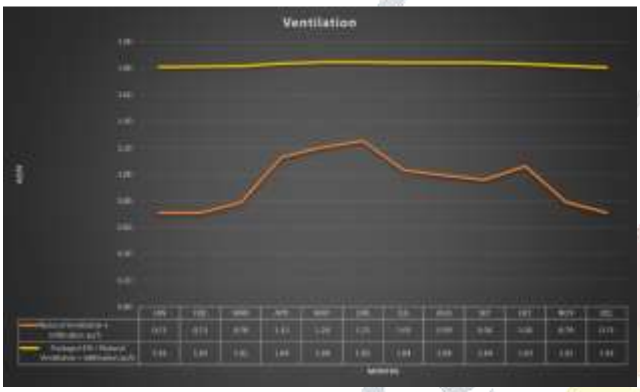

Figure 146. Monthly average air changes per hour.

Proposed passive ventilation strategies are providing enough air changes between (0.7-1.25) in the building hence the guest house has two bedrooms (with crass ventilated), one closed pantry (with one-sided ventilated), and an open balcony. Only bedrooms are having 2.5 air changes individually.

16.3. Fuel totals

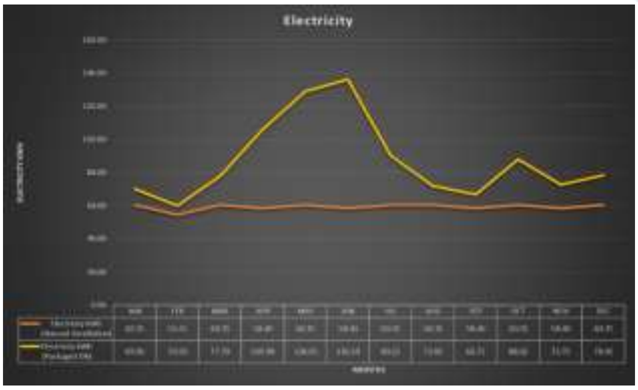

Figure 147. Monthly average fuel totals.

The total energy consumption in a natural ventilated building is **68%** of the actively ventilated building, on 32% of energy consumption can be reduced annually.

16.4. CO_2 Emissions

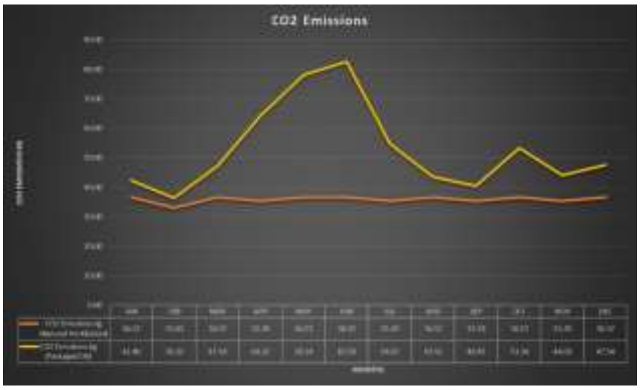

Figure 148. Monthly average CO_2 emissions.

The total CO_2 Emissions in the natural ventilated building is **68%** of actively ventilate the building, on 32% of CO2 Emissions can be prevented annually.

17. CONCLUSION

The energy demand for HVAC can be reduced in the building by integrating passive strategies with various building designs.

The dominant passive design strategies include solar chimney for stack effect and Jali-walls for venturi effects for adequate ventilation inside the building.

Mentioned below are the probable reduction of energy consumption using passive ventilation strategies from the total energy required for the ventilation of the building using active strategies in the proposed building blocks:

67% of the annual energy consumption can be reduced annually in the proposed office building.

58% of the annual energy consumption can be reduced annually in the proposed cafeteria.

32% of the annual energy consumption can be reduced annually in the proposed guest house.

Thus, passive design strategies help in reducing the annual energy consumption efficiently, concerning the total energy required for ventilation of the buildings using active ventilation strategies, which satisfies the research intents.

All Simulation could be done by referring; Building Energy Simulation A Workbook Using Design-Builder ™ (Aviruch, Jyotirmay, Surekha, & Vishal, 2017)