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Report of the Russell Square Theatre

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Abstract

Design of a low-energy, passively ventilated, healthy and comfortable theatre building for Russell Square in the London area. The project utilizes analytical tools—IES VE and CIBS EAM10—to assist in the design of building performance simulations and to analyze and test the effectiveness of building and environmental strategies. The project maximizes the natural ventilation and passive cooling of the theatre, and the building performance simulation is iterated over time to achieve the required environmental objectives for the building's volume flow and CO2 concentration. The building was optimized through the use of solar energy, natural wind and geographical topography, high performance building maintenance structures and good airtightness and shading adjustable technologies to enhance the use of passive technologies, ultimately providing a quality building that meets the project objectives of health and comfort.

Keywords: passive building, passive ventilation system, analytical tools, building performance simulations

1. Introduction and Brief

1.1 Project Introduction

1.1.1 Project Aim

Provide a low energy consumption passive ventilation system and build healthy and comfortable buildings with good quality.

1.1.2 Project Objectives

Understand the basic design principles of passive and natural ventilation design and engineering, and formulate a series of appropriate environmental objectives according to design specifications. Using environmental simulation software IES VE and CIBS EAM10 as analytical tools for auxiliary design, building performance is carried out, and the effectiveness of building strategy and environmental strategy is tested and analyzed. Through iteration, until the test results meet the desired environmental targets.

1.2 Design Brief

Table 1. Architectural brief describe the programme and timetabling for the building

Name	**Size**	**Occupancy numbers**	**Occupancy pattern**
Theatre auditorium	100 m^2	100 people maximum	Performances run from 12 pm to 2 pm and from 6 pm to 8 pm each day.

Café	60 m^2	40 people maximum	Variable occupancy through the day, from 8 am to 10 pm.
Reception	20 m^2	-	-
Ancillary spaces	60 m^2	-	-

1.3 Environmental Design Targets

Table 2 shows the indoor environmental targets of the theatre auditorium and the cafe as guidelines for building design.

Table 2. Environmental design targets

Theatre auditorium		
Indoor environment	Design criteria	Source
Thermal comfort	20-24 °C for winter 22-27 °C for summer	BS EN 15251:2007
CO2 concentration	500 ppm above outdoor	BS EN 15251:2007
Natural ventilation	10 l/s/p	CIBSE Guide A
Acoustic environmental	Indoor noise <35 dB(A) Noise from outdoors <55 dB(A)	BS EN 15251:2007
Relative humidity	60-25%	BS EN 15251:2007

Table 3. Environmental design targets for cafe

Cafe		
Indoor environment	Design criteria	Source
Thermal comfort	20-24 °C for winter 22-27 °C for summer	BS EN 15251:2007
CO2 concentration	500 ppm above outdoor	BS EN 15251:2007
Natural ventilation	10 l/s/p	CIBSE Guide A
Acoustic environmental	Indoor noise <35 dB(A) Noise from outdoors <55 dB(A)	BS EN 15251:2007
Relative humidity	60-25%	BS EN 15251:2007

1.4 Natural Ventilation

HVAC systems consume about 68% of the energy in buildings, while buildings with natural ventilation systems not only provide fresh air but also do not consume any energy, overcoming some common health problems (Evola and Popov, 2006). People pay more and more attention to the design of natural ventilation buildings, so this project uses passive thermal regulation technology to carry out natural ventilation and passive cooling to provide a healthy and low energy consumption building for the audience. By using the natural ventilation system, thermal comfort, and good indoor air quality are provided in the closed space, the environmental strategy of the project is defined, and the operation mode of the building in the environment is determined.

The correct design of a naturally ventilated building is a challenging task because it involves very complex physical phenomena (Evola & Popov, 2006). We need to make efforts to make natural ventilation a viable alternative to mechanical systems, learning and using building elements such as atriums, light columns, and solar chimneys to provide residents with a low-energy, healthy natural ventilation building (Back to basics, 2020).

1.5 Site Location Analysis

The construction of the theatre at this location has the following advantages:

- Adequate sunlight, comfortable environment.

Figure 1 shows the wind direction and sun path of the site. The actual picture (Figure 3-7) shows that Russell Square is full of sunshine, there is no occlusion of higher buildings around it, and it has a better natural green shade. Figure 13-15 shows the architectural shadow of the site at different points on the same day.

- Accessibility

As shown in Figure 2, it takes only 150 meters from the project location to the nearest underground station, with four main roads around Russell Square and four bus stations nearby. Traffic is very convenient for the audience.

- Low-level pollution

Figure 8-11 analyzes the pollution level of the site, which is low, with high vegetation coverage and fresh air.

- Low noise level

Figure 12 analyzes noise levels in Russell Square is 60.0-64.9 db, the noise was more intense in the north and east, but noise pollution levels are acceptable.

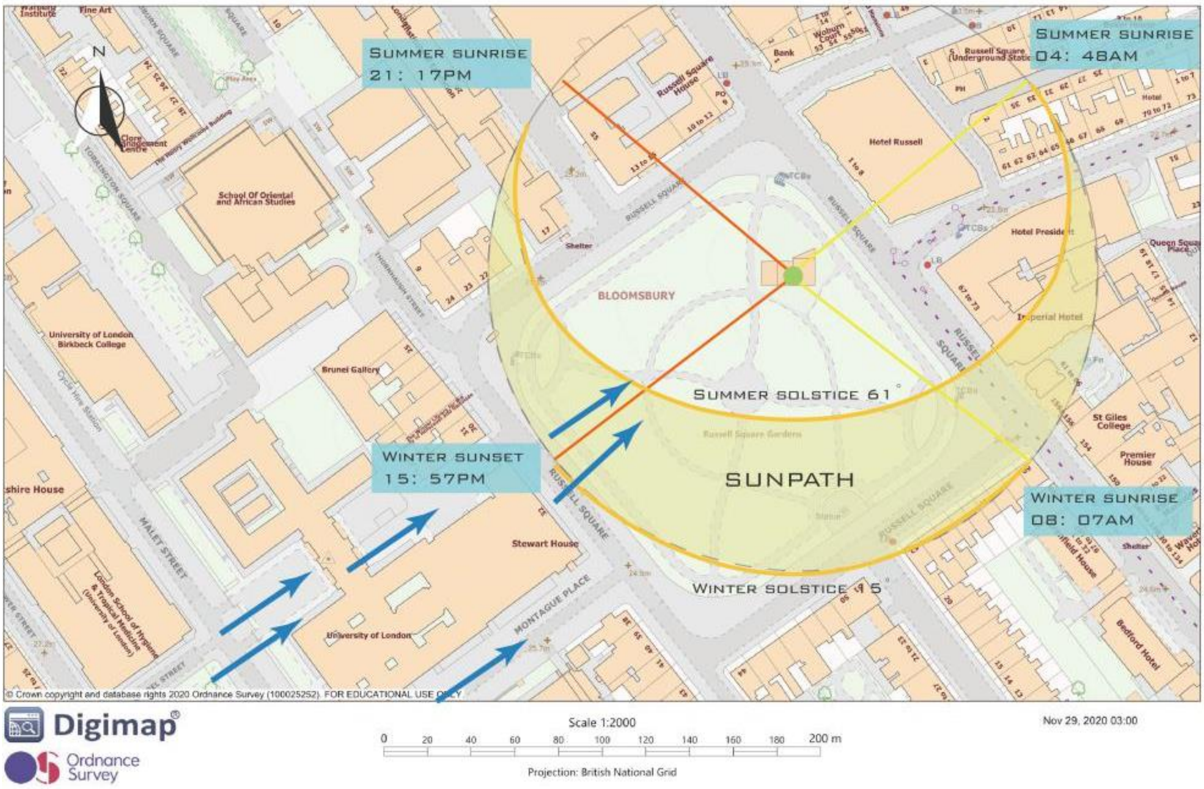


Figure 1. Site analysis about sun path and wind direction diagram

Map source: https://digimap.edina.ac.uk/

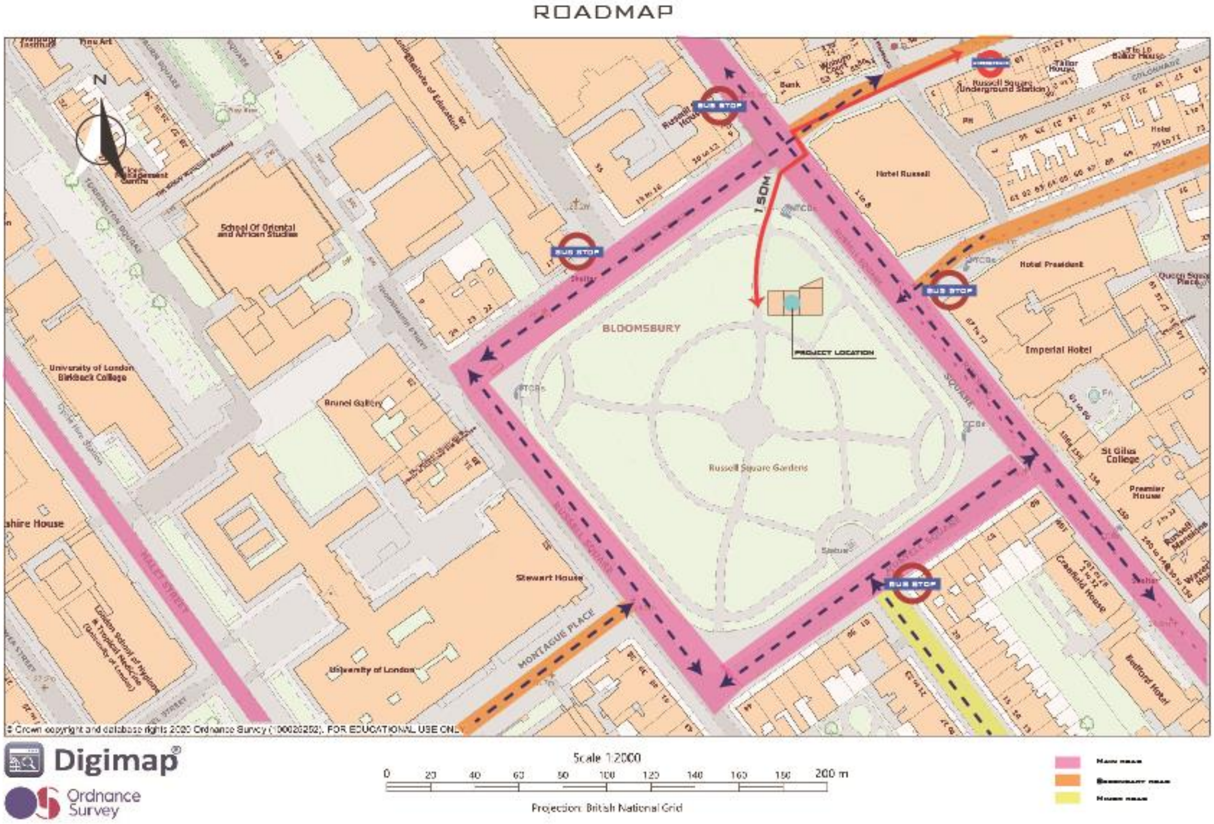


Figure 2. Traffic and public facilities analysis diagram-A road map for the audience to the theatre
Map source: https://digimap.edina.ac.uk/

Figure 3. A view of the existing cafe from the path

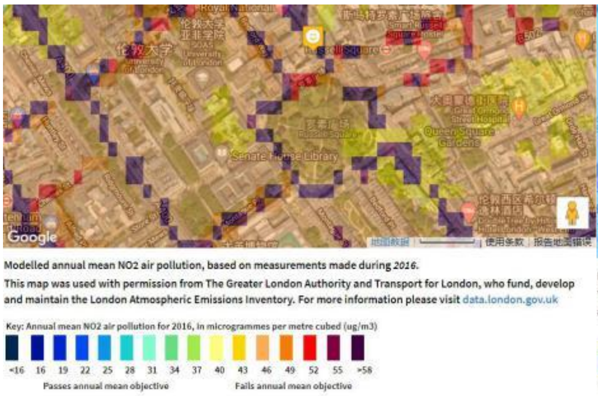
Figure 4. Current cafe within Russell Square

Figure 5. View of cafe from centre of Russell Square

Figure 6. A path into the square

Figure 7. Existing site conditions

Map source: google map



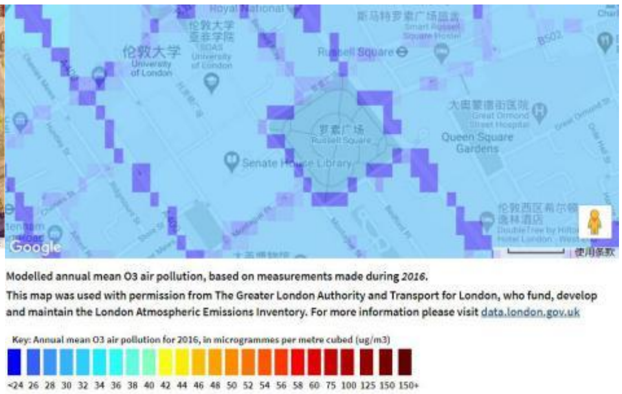
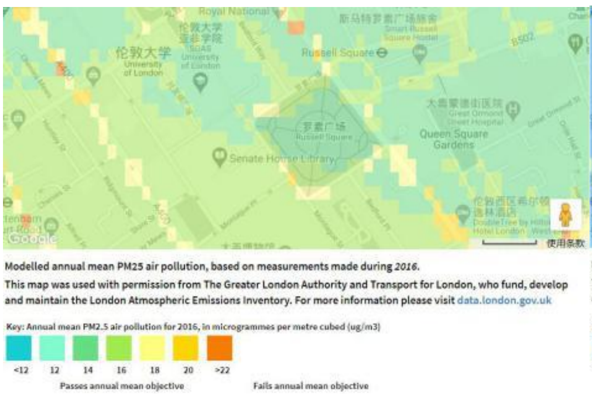


Figure 8. Annual mean NO2 air pollution Figure 9. Annual mean O3 air pollution

(London Air Quality Network Annual Pollution Maps, 2020)

Source: http://suncalc.net/



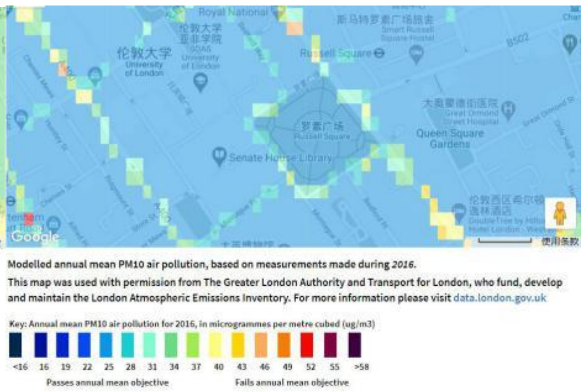


Figure 10. Annual mean PM2.5 air pollution Figure 11. Annual mean PM10 air pollution

(London Air Quality Network Annual Pollution Maps, 2020)

Source: http://suncalc.net/

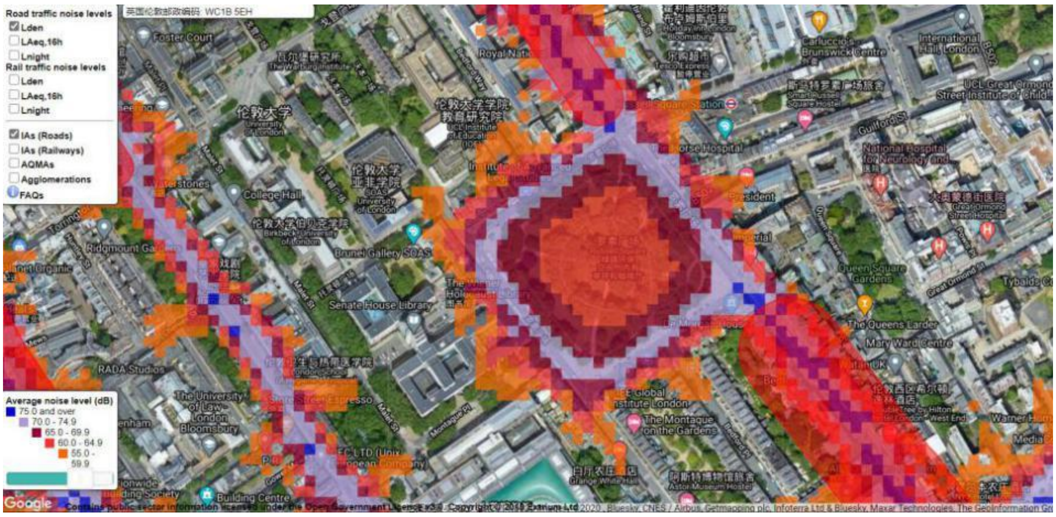


Figure 12. Russell Square noise level analysis diagram (Burdett, 2020)

Map source: http://suncalc.net/

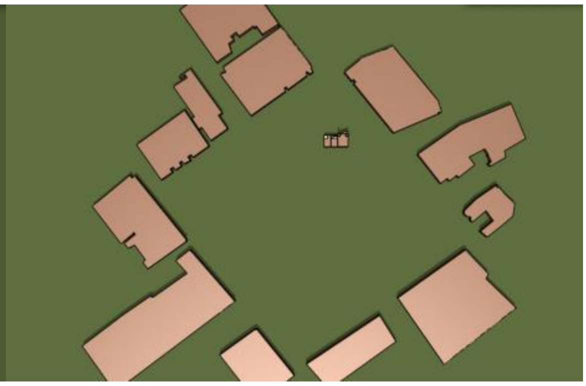


Figure 13. Shading analysis 8 AM 8th Sep

Figure 14. Shading analysis 12PM 8th Sep

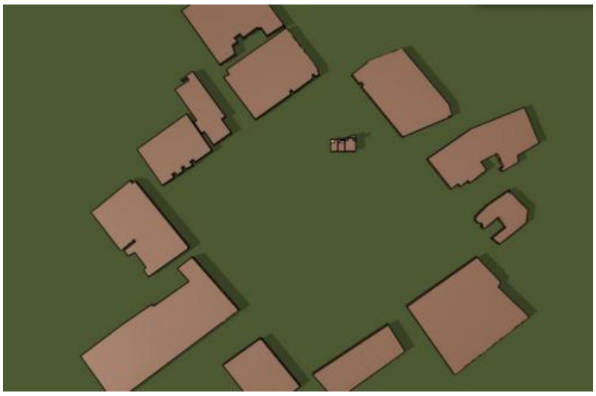


Figure 15. Shading analysis 16PM 8th Sep

2. Architectural Strategy

2.1 Architectural Layout Design

Architectural layout (figure. 16-20), considering the size f each functional area and the audience circulation route, the reception connects the coffee shop, the hall, and the auditorium. Through the analysis of temperature, noise, solar energy and wind, it can be concluded that the most suitable layout is to set the opening on the south facade to obtain wind and sufficient natural light, and to avoid noise from the north and east into the building.

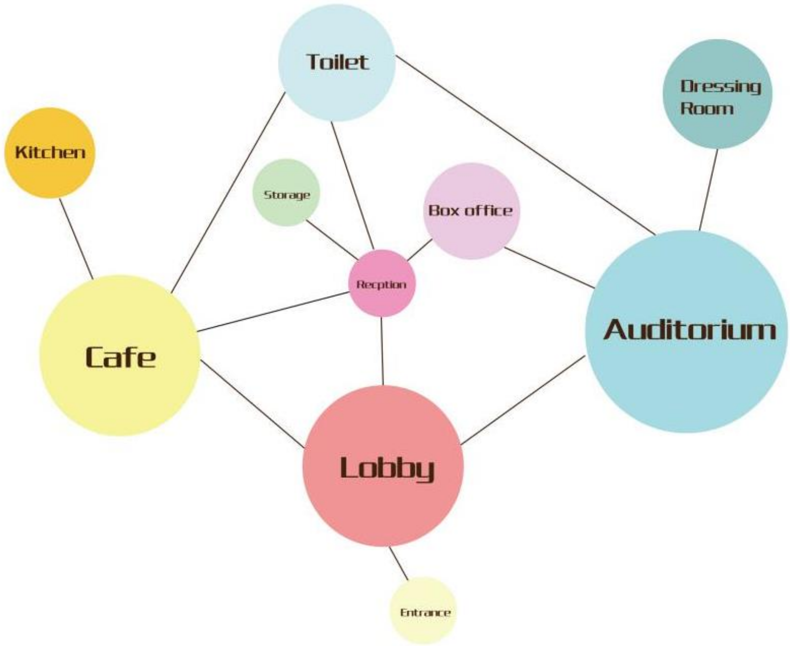


Figure 16. Bubble diagram for layout

The interior space of the building is simple, and the lobby and cafe connect the path of Russell Square. While the auditorium built by secondary materials is located on the right side of the lobby and connected to other spaces by the reception.

Figure 17. Architectural layout (scale1:500) and the surrounding trail

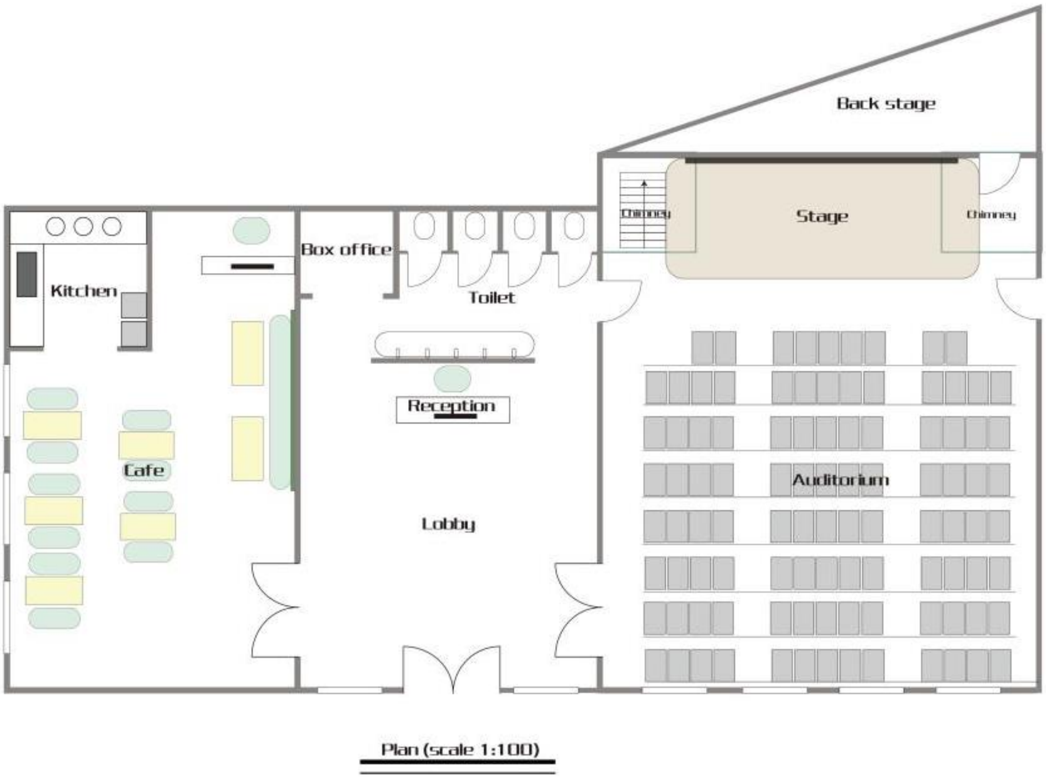


Figure 18. Building plan (scale1:100)

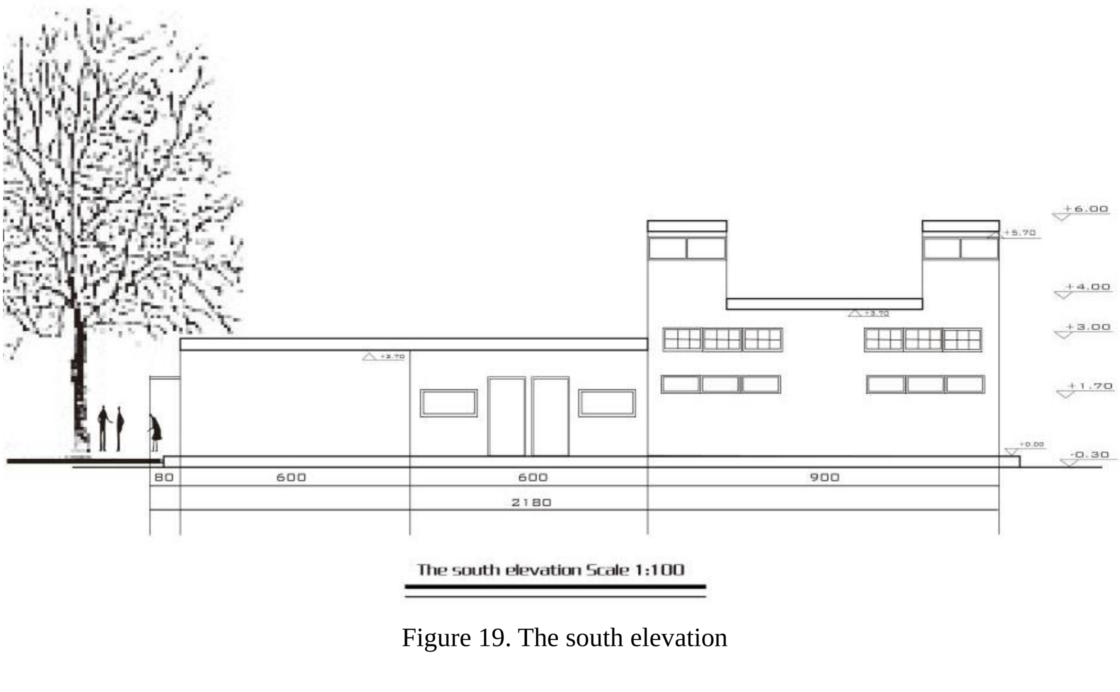


Figure 19. The south elevation

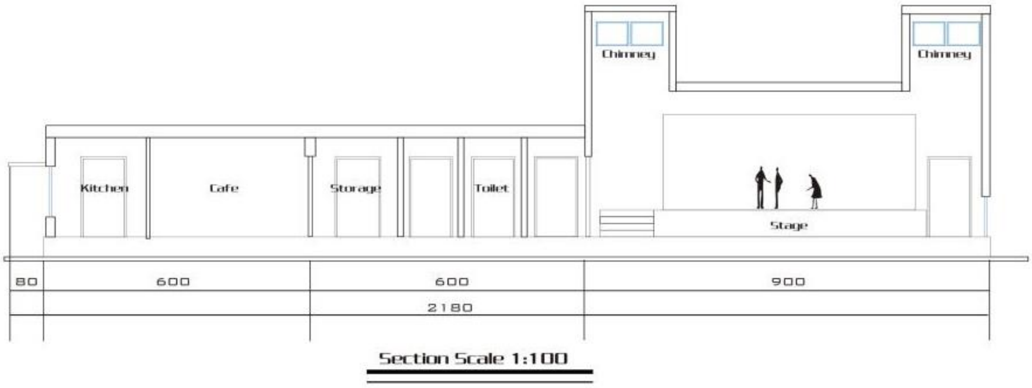


Figure 20. Architectural sections

2.2 Low-Energy Natural Ventilation Buildings

Passive ventilation of low-energy buildings is a new product of the industry, also shows significant advantages in the concept of environmental protection, technical level, and comfort (Khanal & Lei, 2011). Low-energy buildings can effectively avoid environmental pollution and waste of resources and save production costs (Mahdavi and Doppelbauer, 2010).

To avoid overheating inside the building, the theatre architectural strategy is to maximize the use of a passive natural ventilation system in summer to provide a comfortable indoor environment for different spaces. The architectural design ensures the normal airflow in the room and strengthens the degree of outdoor shading to make the environment reach the comfort required by the audience. The wall adopts heat preservation and insulation technology, and the roof is laid with insulation board to break the heat transmission, so as to ensure the indoor temperature is appropriate in summer, and effectively reduce energy consumption. The comfortable environmental condition is that the indoor temperature does not exceed 28℃, and the relative humidity of indoor air does not exceed 60% (Olesen, 2007). The architectural design strategy of passive natural ventilation with low energy consumption is shown in figure 23. Using inorganic active wall insulation materials, such as heat insulation, energy-saving, the indoor temperature can be increased by 6-10℃ in winter, and the indoor temperature can be reduced by 6-8℃ in summer to meet the demand of energy saving (Jin, 2009).

3. Environmental Strategy

Environmental strategy to achieve the environmental design targets previously set, temperature, CO2 concentration, relative humidity, etc., According to the subjective and objective conditions of the change and development of different countermeasures. The building should be in harmony with the surrounding environment and should not destroy the original ecological environment system (Allard & Allard, 1998).

- The development of thermal environment should make full use of the natural ventilation mode of wind pressure and hot pressure, and optimize the indoor thermal environment of the building through the design methods of building structure, indoor space layout and structure.
- The construction, material, direction and greening of the building should be optimized.
- The optimization of light environment should be designed to make full use of natural lighting and increase the reflection system to provide light comfort.
- From the starting point, the middle and the end point, the noise is controlled to optimize the building acoustic environment.
- Using passive natural ventilation strategy

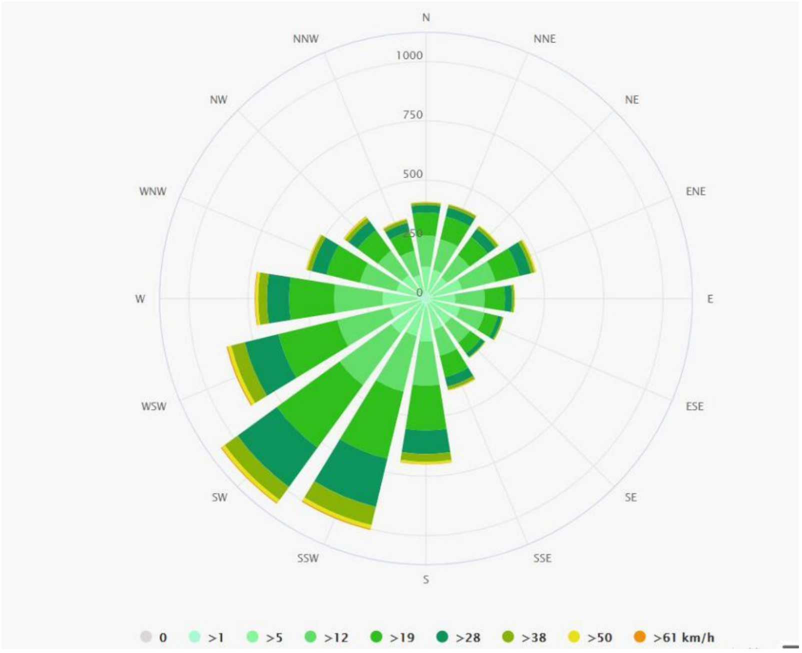


Figure 21. Wind roses for Russell Square

Source: www.meteoblue.com

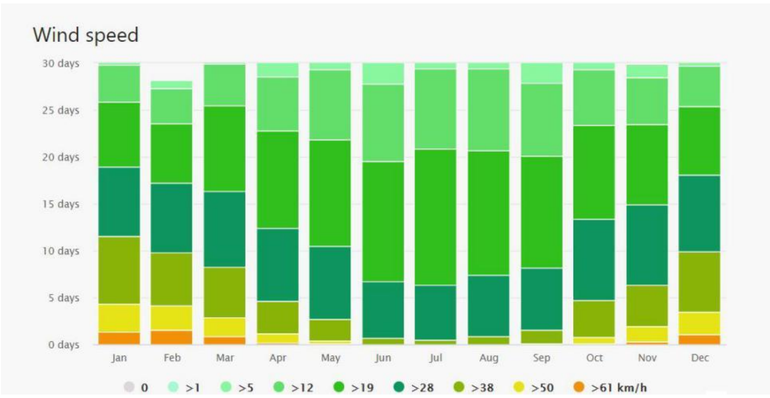


Figure 22. Wind speed analysis at Russell Square

Source: www.meteoblue.com

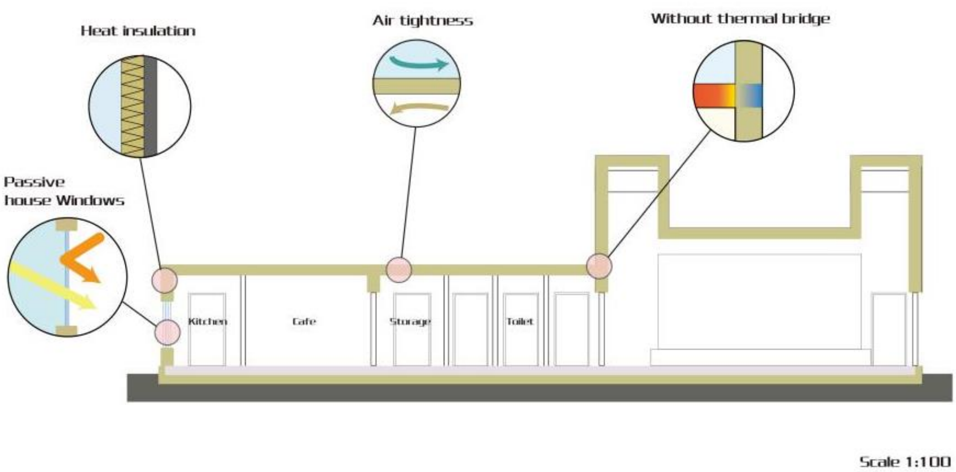


Figure 23. Passive natural ventilation for low energy building design strategy

3.1 Window Planning

Ventilation affects the experience and comfort of the audience and is the focus of architectural design strategies (KHANAL, R. & LEI, C., 2011), In the process of planning and design the wind direction is analyzed, the building layout is arranged reasonably, and the appropriate ventilation strategy is selected.

By Russell square wind rose (Figure. 21) and the wind speed chart (Figure. 22) analysis, understand to the scene of the wind direction and wind speed, window is located in the building on the west side of the cafe because southwest strong to the introduction of the wind indoor ventilation. Window is located in the building on the east side of the auditorium is affected by the northeaster, so choose complex ventilation ventilation strategy can bring comfort to the auditorium.

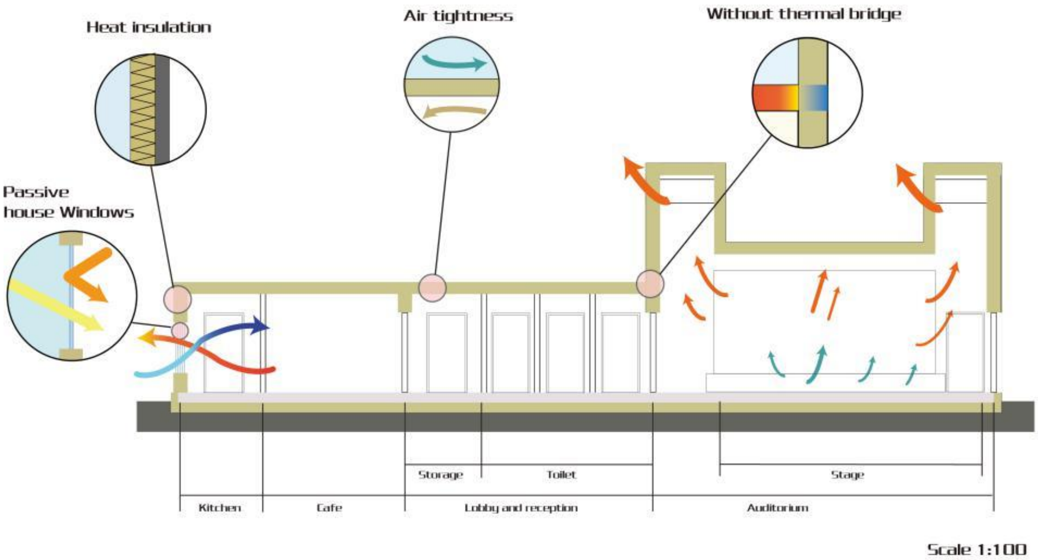


Figure 24. Passive natural ventilation for low energy building design strategy

Natural ventilation systems are introduced into most performance and workspace. Natural cold air enters from the window on the front and right side of the building, after heating the indoor flow of people and lights, slowly rises and drains from the towering chimney. The design of the system (Figure. 24) allows the theater to obtain a steady stream of fresh air in spring, summer and autumn without relying on a large number of mechanical ventilation systems.

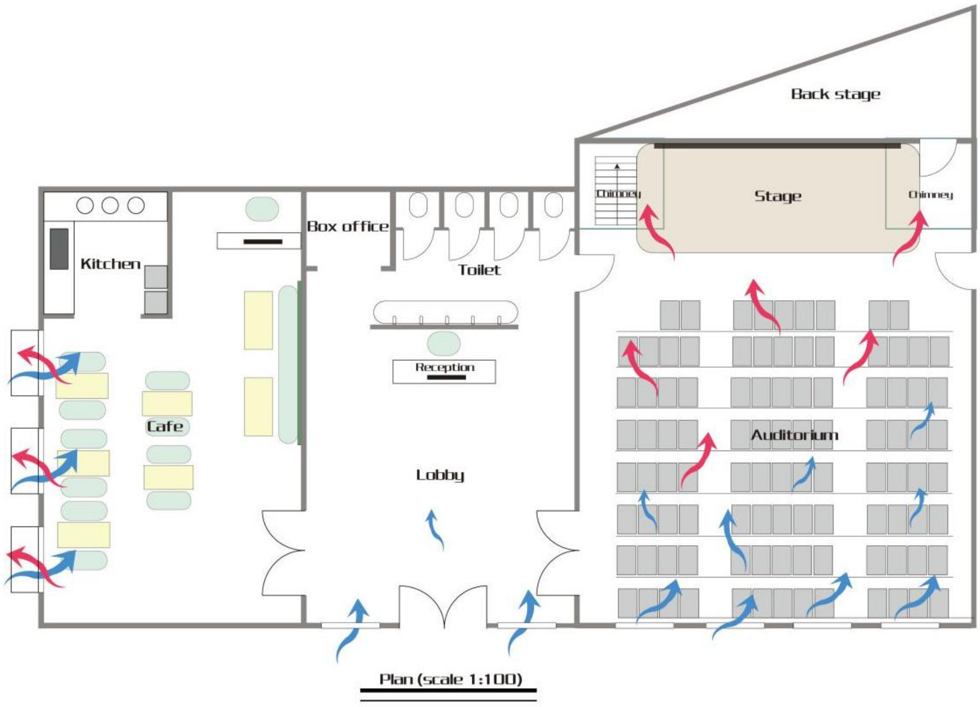


Figure 25. Passive natural ventilation for low energy building design strategy

Windows are opened to the west and south of the building, away from the noise of cars on the streets to the north and east. The café driven by buoyancy through two identical vents; the auditorium is designed according to case 6, and the design of the crowded area attaches importance to the design of air convection, inducing fresh air into the auditorium space, all the stale air passes through the upper outlet from the bottom of the seat to solve the problem of the exchange of hot air between the upper layer of the auditorium and the external gas, fully guarantee the air quality of the internal circulation, and alleviate the influence of the external temperature on the indoor environment.

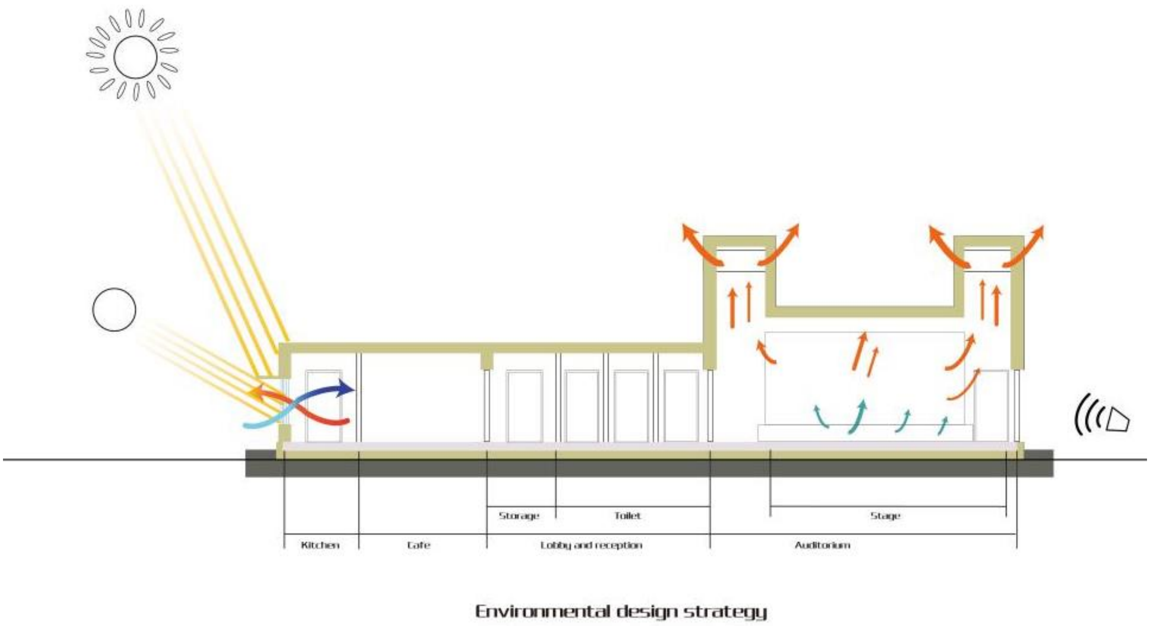


Figure 26. Environmental design strategy

The heat accumulated in the thermal mass during the day is released at night. Summer night outdoor temperature is usually lower than indoor temperature (Figure. 27-33), so use night ventilation to cool the building (Lomas, 2007). The combination of thermal mass technology and night ventilation technology can achieve the design targets of low energy consumption building.

3.2 Thermal Mass

Passive low energy consumption cooling buildings conform to natural factors, do not consume conventional energy, use heat storage function of thermal mass and reduce energy consumption, which is an important means of passive ventilation buildings. Through the indoor heat mass to accumulate heat, the heat release plays a positive role in indoor air conditioning (Jin, 2009). It is necessary to use thermal mass to store heat and reduce the unstable range of indoor temperature and wall temperature (El Fouih & et al., 2012).

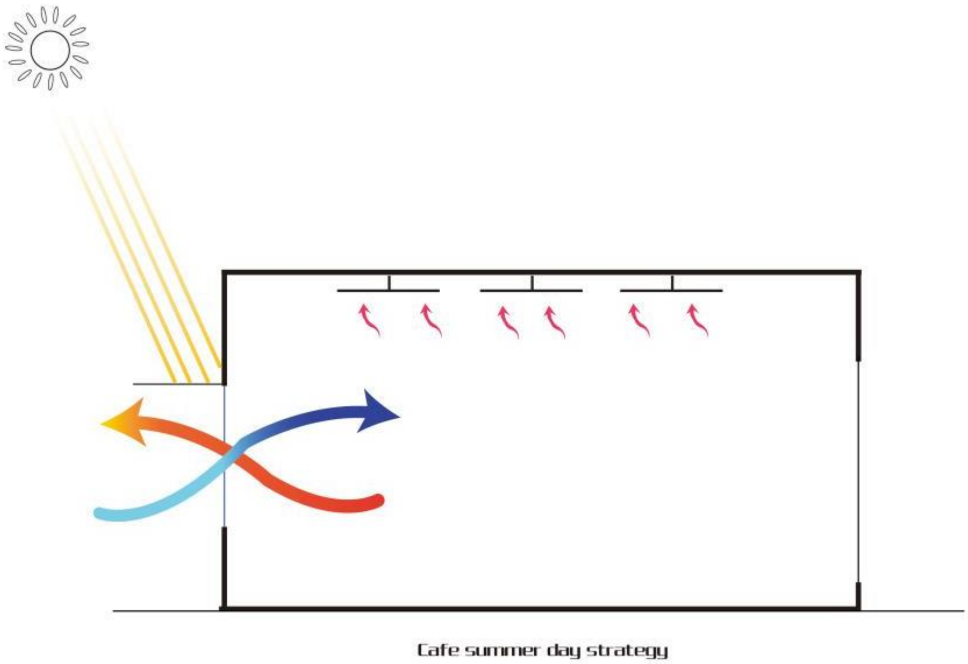


Figure 27. Cafe summer day strategy

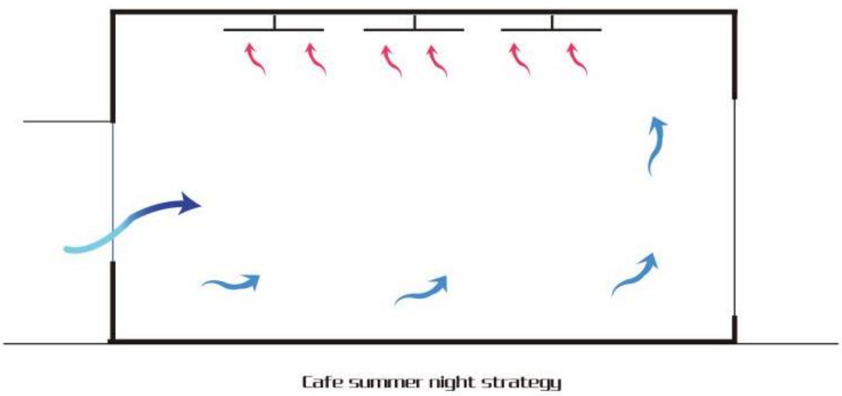


Figure 28. Cafe summer night strategy

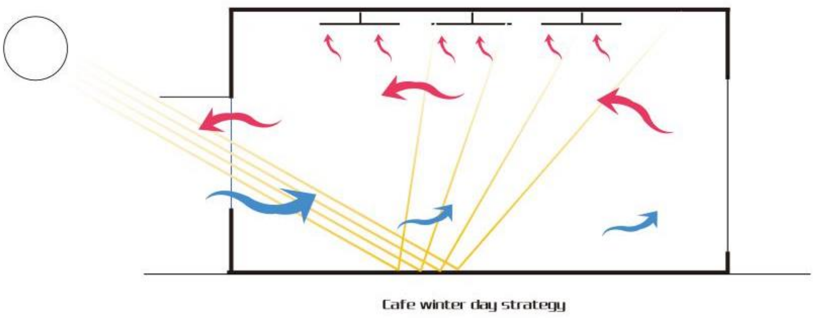


Figure 29. Cafe winter day strategy

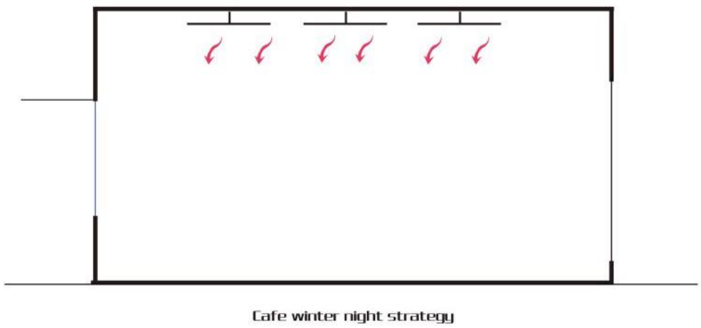


Figure 30. Cafe winter night strategy

In order to cool the building at night, indoor use of thermal mass (Figure. 27-33). During the summer, heat absorbed by the thermal mass is partially released, and a part is stored and delayed to release heat, keeping the indoor temperature in a comfortable and acceptable range (22-27 °C). This measure avoids the problem of overheating and discomfort caused by solar radiation. In winter, the heat obtained from solar radiation is absorbed during the day and slowly released indoors at night, which makes the internal air temperature rise, and the rising space simultaneously introduces fresh and cool outdoor air. In order to ensure the minimum air flow in winter, the higher position of the window requires the installation of controllable ventilators, the introduction of air for the building and the comfort of the indoor environment (20-24 °C) (Clayton, 2000).

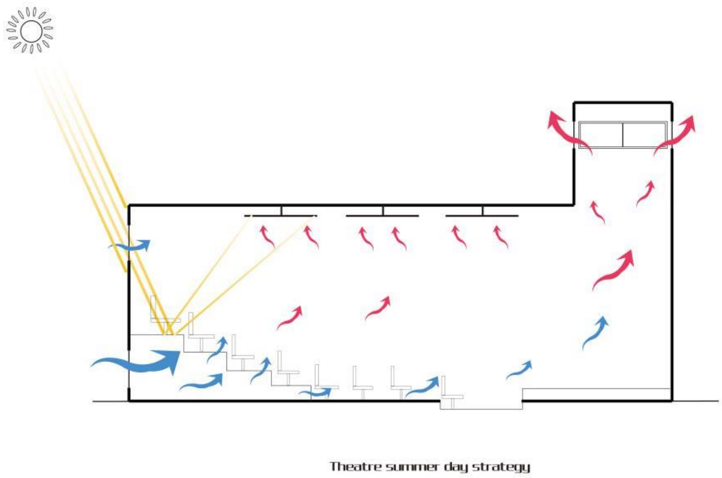


Figure 31. Theatre auditorium summer day strategy

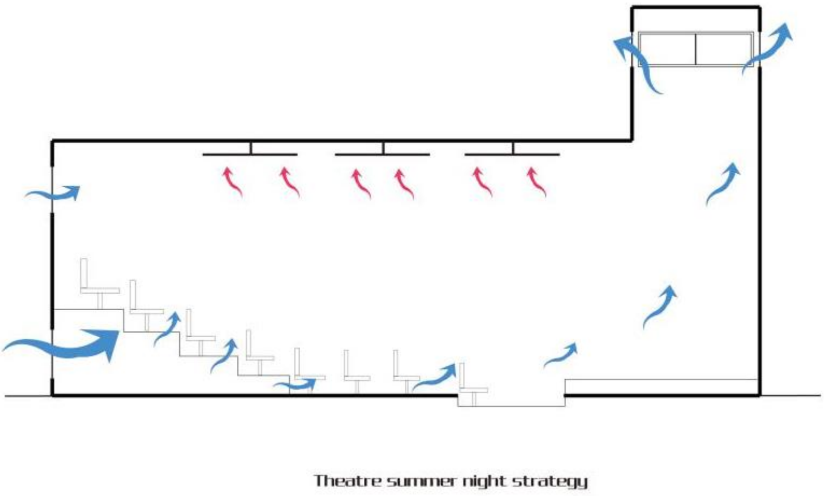


Figure 32. Theatre auditorium summer night strategy

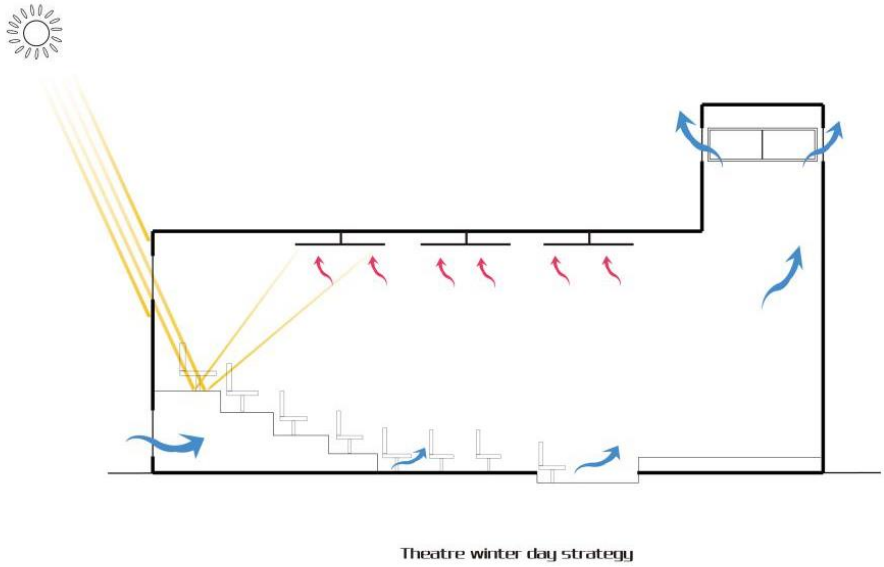


Figure 33. Theatre auditorium winter day strategy

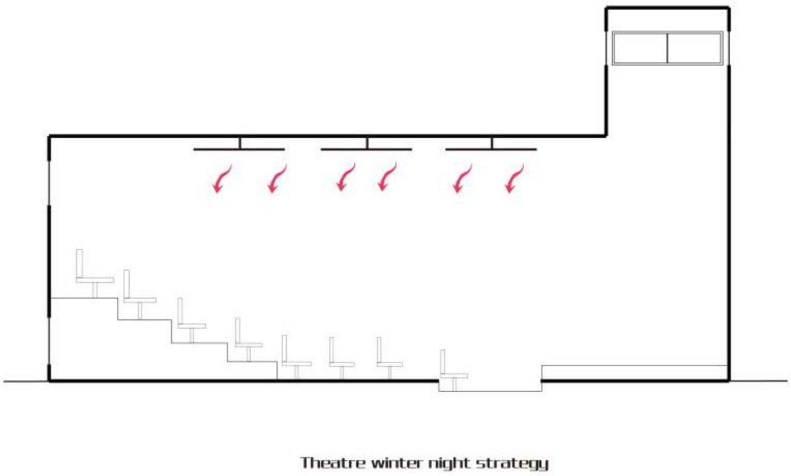


Figure 34. Theatre auditorium winter night strategy

3.3 Noise

To control the noise generated by the auditorium to cause discomfort to the crowd outside the building, and to control the impact of car noise from busy streets on the auditorium, and to reasonably control the noise range (Indoor noise <35 dB(A), Noise from outdoors <55 dB(A)), some measures are needed to solve these problems. The opening of the building is away from the noise source, provision of barriers, increases the sound insulation effect of the building enclosure (BS8233,2014).

4. Design Stage Calculations

Use CIBS EAM10 to design ventilation inlet and outlet dimensions and ensure that indoor CO2 concentrations are met when designing inlet dimensions.

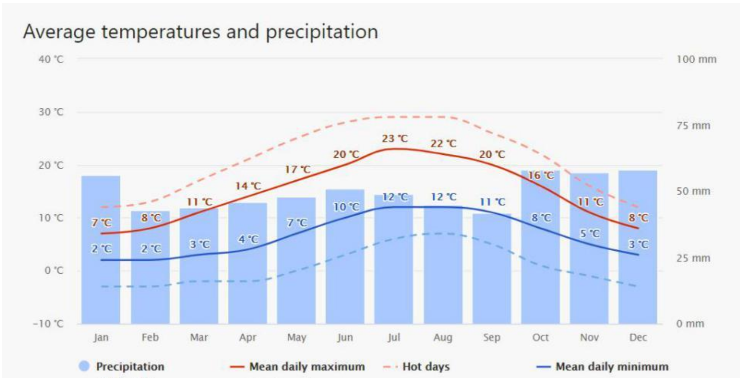


Figure 35. Average temperature and precipitation in Russell Square

Source: www.meteoblue.com

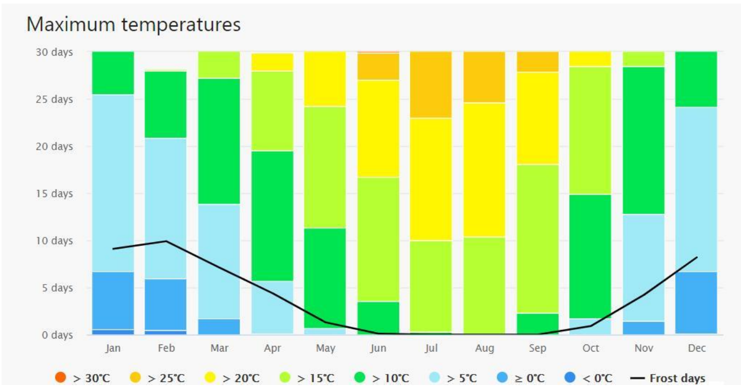


Figure 36. Maximum temperature in Russell Square

Source: www.meteoblue.com

CIBSE AM10 Design tool for isolated spaces	
Cases 1 and 2 - Single sided ventilation through buoyancy alone	
Required flowrate (m3/s)	1.200
Number of openings	1
Discharge coefficient	0.25
Outside temperature (C)	22.0
Inside temperature (C)	26.0
Height of opening (m)	1.200
Size of opening (m2)	12.095

Figure 37. Single sided ventilation through buoyancy alone in summer

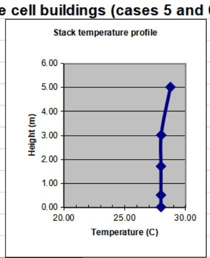
Cases 1 and 2 - Single sided ventilation through buoyancy alone	
Required flowrate (m3/s)	1.200
Number of openings	1
Discharge coefficient	0.25
Outside temperature (C)	7.0
Inside temperature (C)	11.0
Height of opening (m)	1.200
Size of opening (m2)	11.788

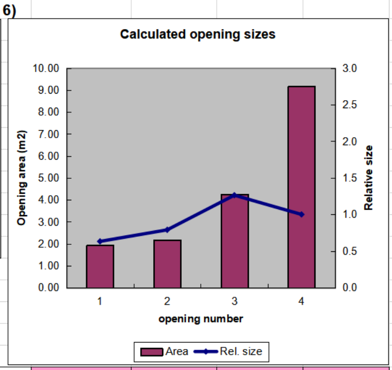
Figure 38. Single sided ventilation through buoyancy alone in winter

Cafes use case 1 to calculate the size of opening in summer and winter. The average outdoor temperature in summer is 22 degrees and the average outdoor temperature in winter is 7 degrees (Figure. 35-36). And the required flow rate according to the internal gains, indoor and outdoor temperature difference, and the number of occupants was calculated 1.2 m3/s.

CIBSE AM10 Design tool for single cell buildings (cases 5 and 6)

Temperature data	
Outside temperature (C)	25.0
Stack temperatures (C)	
at a height of X (m)	6.0
the temperature is (C)	31.0
at ground level it is (C)	28.0
Stratification index	7
Wind data	
Met wind speed (m/s)	0.00
Building height (m)	6.00
Terrain type	Use meteorological value
Site wind speed (m/s)	0.00





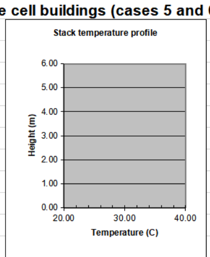
Opening data

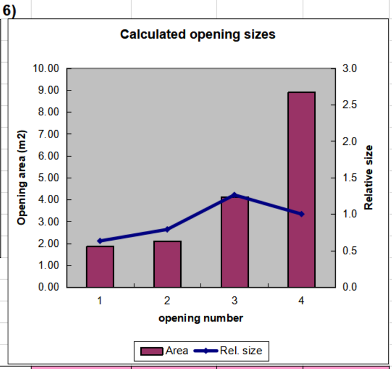
Opening Number	Height m	Cp	Flow m3/s	Cd	Press drop (Pa)	CdA (m2)	A (m2)	Relative size
1	0.5	0.25	0.950	0.61	0.3825	1.1757	1.9274	0.63
2	1.7	0.25	0.860	0.61	0.2450	1.3299	2.1801	0.79
3	3	0.25	1.050	0.61	0.0958	2.5973	4.2578	1.26
Outlet	5	-0.10	-2.860	0.61	-0.1526	5.6031	9.1855	1.00

Figure 39. Single cell buildings in summer

CIBSE AM10 Design tool for single cell buildings (cases 5 and 6)

Temperature data	
Outside temperature (C)	7.0
Stack temperatures (C)	
at a height of X (m)	6.0
the temperature is (C)	13.0
at ground level it is (C)	10.0
Stratification index	7
Wind data	
Met wind speed (m/s)	0.00
Building height (m)	6.00
Terrain type	Use meteorological value
Site wind speed (m/s)	0.00





Opening data

Opening Number	Height m	Cp	Flow m3/s	Cd	Press drop (Pa)	CdA (m2)	A (m2)	Relative size
1	0.5	0.25	0.950	0.61	0.4330	1.1401	1.8690	0.63
2	1.7	0.25	0.860	0.61	0.2773	1.2895	2.1140	0.79
3	3	0.25	1.050	0.61	0.1084	2.5186	4.1289	1.26
Outlet	5	-0.10	-2.860	0.61	-0.1728	5.4332	8.9069	1.00

Figure 40. Single cell buildings in winter

When the building form is flowing, the atrium can be used as an exhaust pipe. The design of the same per capita vent size at the atrium exit and at the top of the building ensures that the air flows forward and minimizes the possibility of the air flowing in the wrong direction. The size of the high window increases to make up for the reduction of chimney pressure in the atrium, thus avoiding the overheating of the high rise. The function of the high opening is to assist the ventilation of auditorium. The press drop, CDA, area and relative size of the opening can be calculated according to the number and height of the windows in the auditorium.

5. IES VE Simulation Results

The model uses IES VE to simulate building performance, with nine iterations from the first test to the sixteenth.

- Selection of ventilation strategies
- Determine and modify window sizes using CIBS EAM10
- Increase in internal gains
- Increase window shading, increase surrounding trees
- Add thermal mass and insulation
- Change of window openable area and max angle open
- Change of occupancy rate and randomness of occupant window opening behavior (based on temperature and carbon dioxide concentration)
- Change ventilation strategy
- Reconfiguration window open profile (summer is different from winter)
- Set annual heating demand and cooling load

Originally, the cafe used case1 ventilation strategy, with windows on the south façade, with no window shading, and the size of the window is 6 m2. The auditorium uses case 5 and 6, windows located around the south facade, the east facade, and the chimney, with an area of 8.6 m2. The internal gains of the model set the number of cafes is always 40, the number of the auditorium is 100, and the income data of lamps and occupants are added.

Passed:	0 rooms:					
Room Name	Room ID	Occupied	Criteria	Criteria	Criteria	Criteria failing
Failed:	2 rooms:					
Room Name	Room ID	Occupied	Criteria	Criteria	Criteria	Criteria failing
cafe	CF000000	100	10.7	56	7	1 & 2 & 3
cheminey	CH000001	100	4.1	15	5	1 & 2 & 3

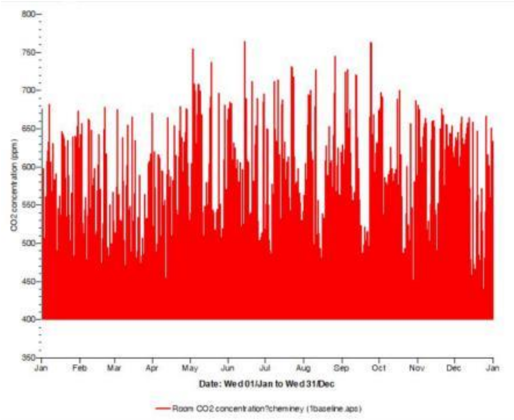
Figure 41. Overheating evaluation table

According to CIBSE TM52 (2013), an adaptive thermal comfort analysis was carried out on the risk of building overheating, and the result was that both the auditorium and the cafe had the risk of overheating.

Although the CO2 concentration of the auditorium in summer is the only 760ppm, which is within the acceptable comfort range, the ventilation volume is huge and the ventilation volume in winter is greater than that in summer.

The problem was found due to the openable area setting too large with the window opening angle and the parameter time design error.

Indoor and outdoor temperatures are close in summer, but there is still a risk of overheating.



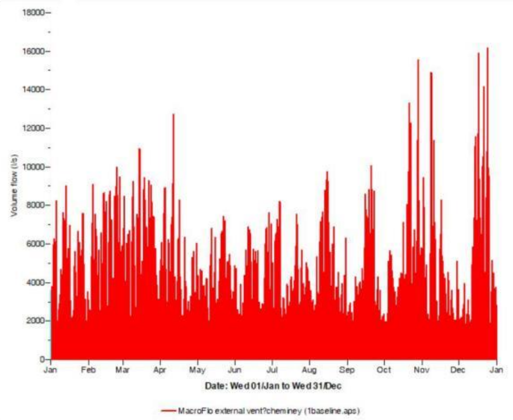


Figure 42. Auditorium CO2 concentration chart Figure 43. Auditorium volume flow chart

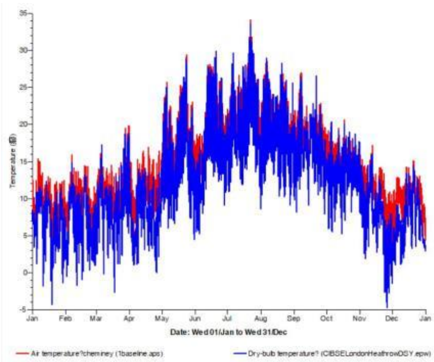
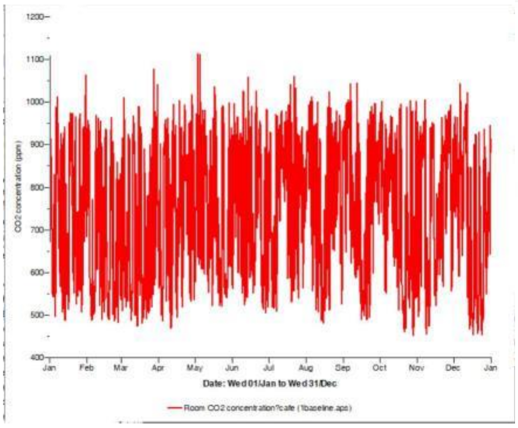


Figure 44. Auditorium indoor and outdoor temperature chart



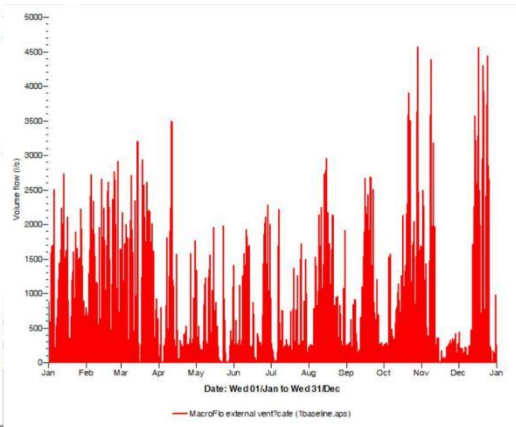


Figure 45. Café CO2 concentration chart Figure 46. Café ventilation chart

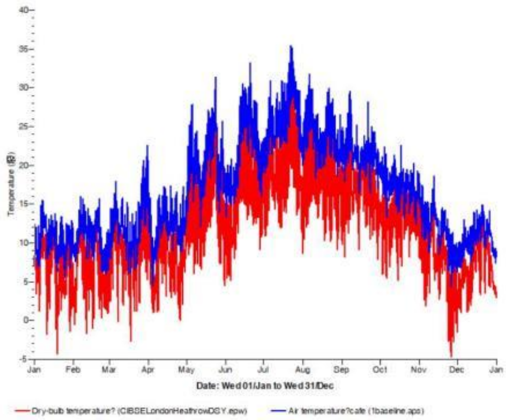


Figure 47. Café indoor and outdoor temperature chart

The indoor CO2 level of the cafe is kept in the range of 450-1100ppm, which is within the comfort range, but the indoor temperature is too high to pass the risk assessment of overheating.

Due to the problems found above, to solve these problems, AM10 was used to calculate the window size again and increase the window size. The cafe was changed from 8m2 to 12m2 in window size, moved to the west facade, and the 0.8m-wide window shading was added. Enlarge the east side Windows of the auditorium and add trees around the building to shade and cool the building.

After modifying the window size, add trees and window shading, the results showed a slight drop in temperature and a significant drop in carbon dioxide levels of about 400 parts per million.

For the floor, roof, external wall, and ground floor of the building, thermal mass and insulation materials with a thickness of 100mm are added respectively to improve the thermal insulation performance of the building. Modifying the different occupancy rates in summer and winter reduces part of the internal gains from the human body. The optimization results show that building performance has changed. Due to the addition of hot blobs, the heat will be dissipated at night, so the temperature in the morning and night is slightly increased by one degree. And daytime temperatures are lower than in the previous simulation, but it still doesn't pass the overheating evaluation.

The iterative process was continued for several times to increase the thickness of thermal mass and insulation materials, increase the size of windows, and modify the random configuration data of the occupant's window opening behavior. The results show a significant change, with the theatre having successfully passed the criteria for overheating evaluation, with indoor and outdoor temperatures similar in summer. However, the cafe still fails to pass the evaluation and still needs to be optimized and modified.

Passed:	1 rooms:						
Room Name	Room ID	Occupied	Criteria	Criteria	Criteria	Criteria	failing
cheminey	CH000001	100	2.1	11	4	2	
Failed:	1 rooms:						
Room Name	Room ID	Occupied	Criteria	Criteria	Criteria	Criteria	failing
cafe	CF000000	100	3.5	35	6	1 & 2 & 3	

Figure 48. Overheating evaluation table

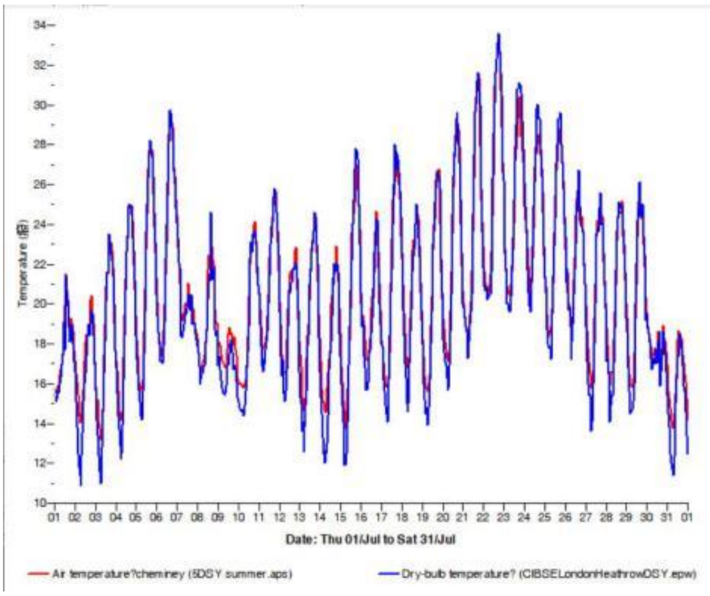


Figure 49. Auditorium summer indoor and outdoor temperature chart

According to the indoor CO2 concentration and the temperature of the environmental targets, the profile of different window opening behaviors in summer and winter was modified. Then change the window openable area to 60% and max angle open to 15%. The results showed that both the cafe and the auditorium had reached the appropriate target range for CO2 concentrations and volume flow, but the cafe was still at risk of overheating in the summer due to high temperatures.

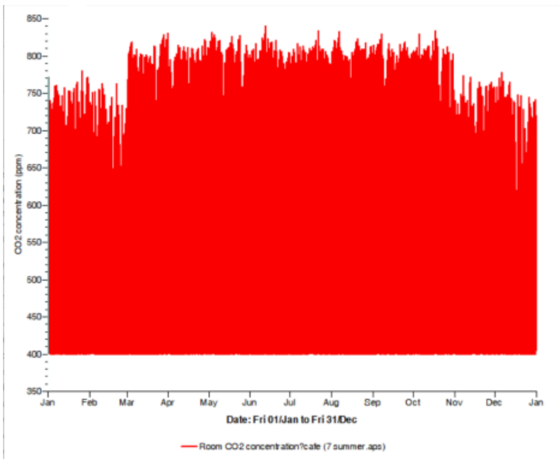


Figure 50. Café CO2 concentration chart

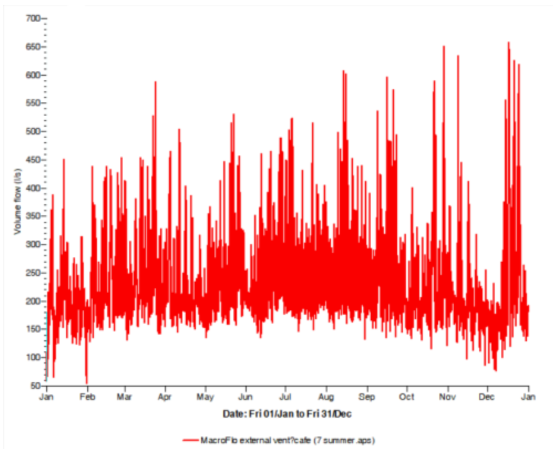
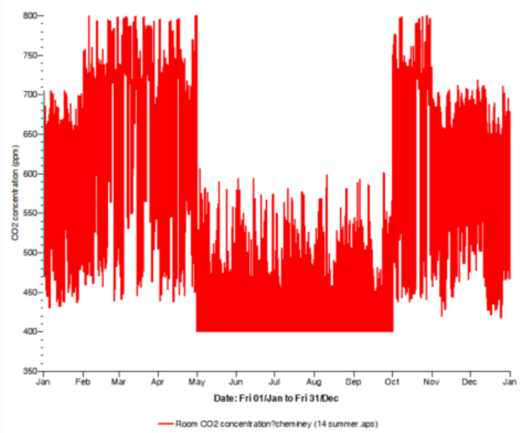


Figure 51. volume Café flow chart

To solve the problem that the temperature of the cafe is still too high in summer, iterative optimization steps are continued for it. Change its ventilation strategy from single-side ventilation to cross-ventilation, and continue to modify the configuration of cafe window profile. The final simulation showed that the cafe was still at risk of overheating, with temperatures exceeding 26 degrees on several days in summer, despite similar indoor and outdoor temperatures.

Passed:	1 rooms:						
Room Name	Room ID	Occupied	Criteria	Criteria	Criteria	Criteria	failing
cheminey	CH000001	100	1.6	8	3	2	
Failed:	1 rooms:						
Room Name	Room ID	Occupied	Criteria	Criteria	Criteria	Criteria	failing
cafe	CF000000	100	1.9	29	5	2 & 3	

Figure 52. Final overheating assessment table



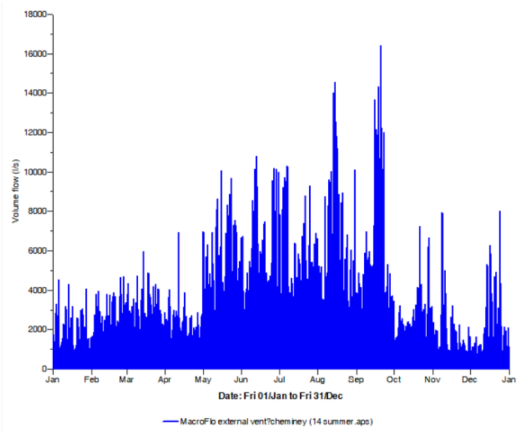
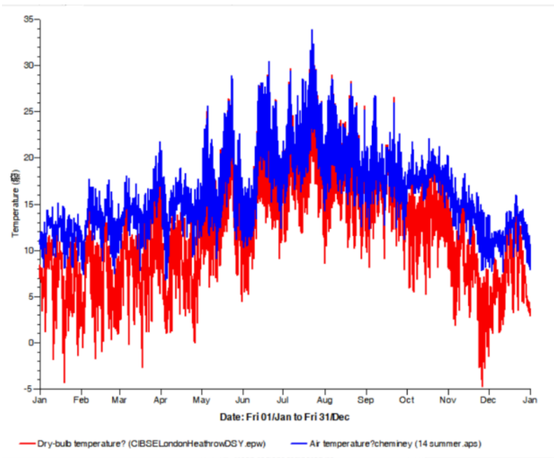


Figure 53. Final auditorium concentration chart Figure 54. Final auditorium volume flow chart



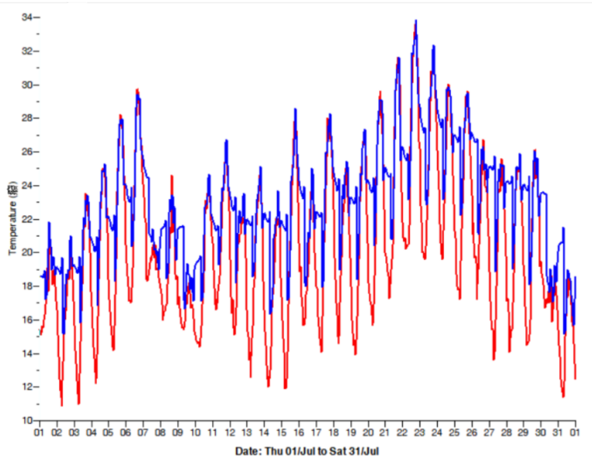


Figure 55. Final auditorium indoor and outdoor temperature chart

Figure 56. Final auditorium summer temperature chart

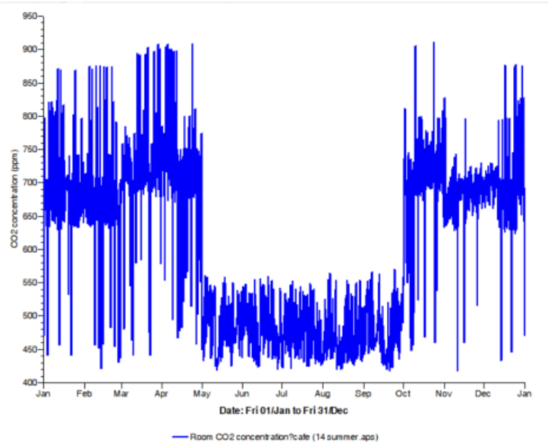


Figure 57. Final café concentration chart

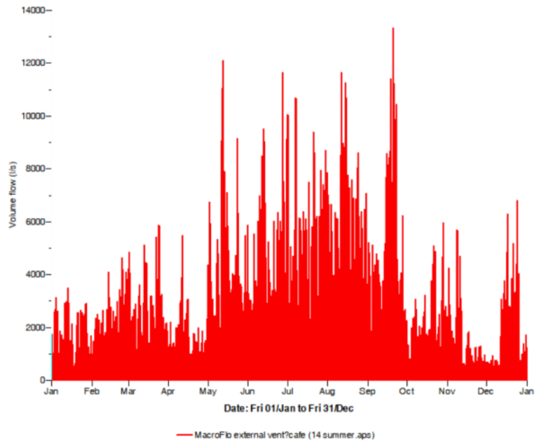


Figure 58. Final cafe volume flow chart

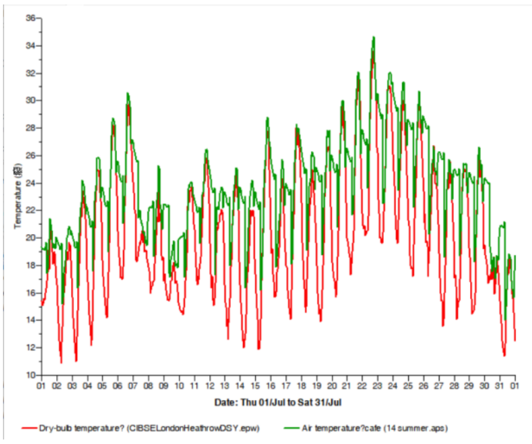


Figure 59. Café summer temperature chart

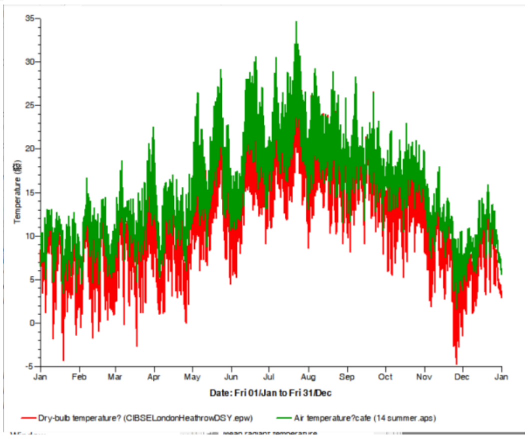


Figure 60. Cafe annual temperature chart

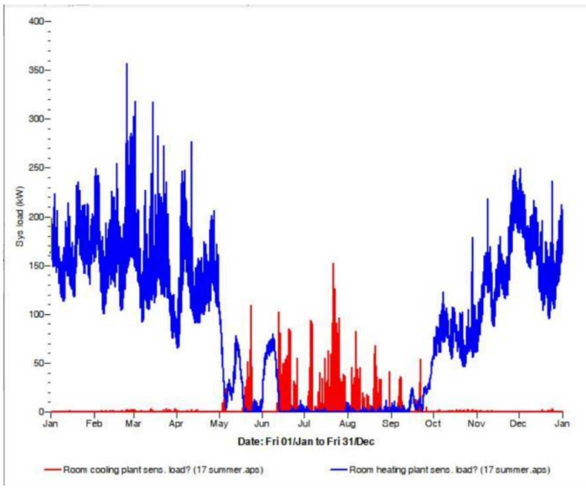


Figure 61. Auditorium heating and cooling load chart

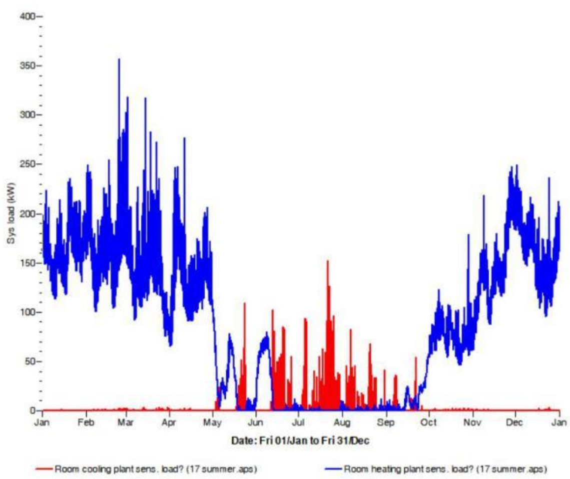


Figure 62. Cafe heating and cooling load chart

6. Analysis of Simulation Results and Impact Upon Design

6.1 Discuss

If the theatre could be built in Russell Square in the future, then suggest the building construction team can optimize the building by taking advantage of solar energy, natural wind, and geographical terrain, and by adopting high-performance maintenance structure and good air-tightness and shading adjustable technology, strengthening the application of passive technology and giving full play to the technical guidance of the strategy (Allard and Allard, 1998).

6.2 Conclusion

To achieve the appropriate environmental design targets, the project has maximized the use of passive thermal regulation technology for natural ventilation and passive cooling of the theatre, and the volume flow and carbon dioxide concentration of the building has reached the target requirements. In tutorial discussions, I was recommended for an iterative design using several measures: adding window shading, altering the window size and angle. However, my project is limited, because there is no mechanical ventilation, heating, and the cooling system added in the interior, so the building temperature cannot reach the target temperature previously designed. The temperature is slightly higher in summer and slightly lower in winter, making the audience unable to feel comfortable in the building.

Due to the temperature was out of the comfort zone and there was a risk of overheating, my project ended up achieving only 80 percent of its environmental goals. In order to achieve the environmental objectives, the next step should be to continue to modify the ventilation strategy of the project, close the entrance above the auditorium (which will improve the ventilation performance of the entrance at the bottom), and thicken the insulation.

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