Research Article GU J Sci, Part B, 10(2): 93-109 (2022)

Gazi University

Journal of Science

PART B: ART, HUMANITIES, DESIGN, AND PLANNING

http://dergipark.gov.tr/gujsb

Using Biomimetic Architectural Design Approach for Passive Natural Ventilation in Educational Buildings

Sahar TOHIDI[1,*], Mehmet Tayfun YILDIRIM[2]

[1] *0000-0002-5990-1028, Gazi University, Graduate School of Natural and Applied Sciences, 06500, Ankara, TURKEY*
[2] *0000-0003-4160-8314, Gazi University, Architecture Faculty, Department of Architecture, 06570, Ankara, TURKEY*

Article Info

Received: 27/04/2022
Accepted: 06/06/2022

Keywords

Architectural Design,
Biomimetic,
Natural Ventilation,
Passive Ventilation,
Educational Buildings

Abstract

The indoor air quality and fresh air in the buildings are important for the users' health. This requirement is especially important for intense indoor users such as offices, educational institutions, industrial buildings, and hospitals. According to the World Health Organization [1]. the number of patients in buildings that have not refreshed air, increases by 4.3 million people in the world per year. Passive system elements such as air inlets, windows and active system electro-mechanical equipments are used to obtain air ventilation. Active electro-mechanical air conditioning and ventilation systems require high installation, operation, and electricity costs. This study aims to offer a passive ventilation system that consumes zero energy in building design. The university lecture spaces that are used by intensive students were chosen as the case study. As a method, the termite nest ventilation system was offered to use in architectural design as a nature-inspired (biomimetic) approach. Sample faculty was modeled in 3D in a CAD environment. External wall air inlets and chimney outlets were placed in the lecture halls of the architectural department. Next, the use of air by the students and the supply of fresh air were simulated by Energy Plus software. The results showed that the recommended system has no open windows to prevent noise from outside and cold air in the winter. Also, it consumes no electricity energy, has a low initial investment cost, and does not involve any operating costs. In conclusion, that zero-energy, low cost, fresh air aimed design is appropriate for buildings such as educational and other intense user buildings.

1. INTRODUCTION

Providing indoor fresh air for users in buildings and refreshing the polluted air is important for the user's health. Fresh air is a critical component for all buildings, especially for offices, educational buildings, and industrial and health buildings. According to the World Health Organization (WHO), the number of patients in buildings that have not supplied their interior ventilation system increases by 4.3 million per year [1]. These diseases are (34%), chronic heart disease (26%), and obstructive pulmonary disorder (22%). Pneumonia and lung cancer account for 12% and 6% of patient losses. In this case, more than 50% of pneumonia deaths in children under 5 years of age are linked to indoor air pollution [2]. Lack of oxygen and fresh air in buildings reason of symptoms such as headache, fatigue, and eye, skin irritation in short periods [3].

Educational buildings that are crowded, intense user environments are among the important buildings to ventilate. Today, buildings are ventilated with active electro-mechanical technologies and passive systems such as windows, air inlets and chimneys.

Sustainable, "zero energy" and zero carbon emission designs have gained importance in architectural design in last decades instead of the high pre-investment and operating costs of electro-mechanical (HVAC, heating, ventilation, and air conditioning) systems.

---

* Corresponding author, email: saharato200@gmail.com

This study aims to provide fresh air in education buildings by using a natural ventilation system. For this purpose, the “termite ant nest” ventilation system was inspired and used for educational buildings as a biomimetic approach. The proposed passive ventilation system was modeled in Design Builder simulation software. “Air consuption by students”, “Required fresh air gain” and “Exhaust of polluted air” simulations, “time /speed/quantity” calculations were obtained.

2. VENTILATION METHODS AND BUILDING BIOLOGY

Building biology is a branch of science that reveals the effects of buildings on our health. Today, 90% of our lives are spent in indoor environments like workplaces and residences [3]. Lighting the buildings with natural daylight, supplying fresh air to the users, effects of materials on human health and acoustic precautions to prevent noise are the major fields in building biology.

This concept gains importance, especially in buildings with a high human density, such as housing, shopping malls, educational buildings, offices, public administrative buildings, and health facilities. In buildings where the air quality is not in sufficient level, symptoms such as headache, fatigue, and eye and skin irritation may be encountered in the short term, and lung, heart, and psychological problems may be encountered in the long term [3]. Research by the International Center for Indoor Energy has revealed that the amount of clean air has a significant impact on the productivity and lives of users [4].

A person needs an average of 7 m3 of fresh air per hour. However, in environments such as sports and factories, this quantity reaches 20 m3. During respiration, carbon dioxide and water vapor are produced by using oxygen of the air in lungs. The amount of oxygen that people need is related to their weight, age, nutrition, and actions [5]. The temperature of the air exhaled by respiration is 35°C (human temperature), and its relative humidity is 95% [6].

The necessity of the fresh air quantity is variable due to human working types according to the International Indoor Air Quality Center (industry labor, student, office employment, etc.). This varies from 3, 10, and 30 lt/sec per person for different job types in the same period. The results showed that the work efficiency increased depending on the fresh air. [7].

According to the measurements of the European Union at Indoortron made for “Indoor Air Quality Laboratory” in Ispra, Italy, people are affected by indoor air pollution 2 to 5 times more than the outdoor environment [8].

The used air gets warmer due to breathing heat and increase indoor heat in the buildings. This condition causes low-high pressure in the building and colder air comes from outside. Its speed, behavior, directions of air movement, distribution of pressure zones and pressure levels are important for providing the desired ventilation level in the buildings with natural methods [9]. In this context, active and passive systems are used to renew the indoor air and bring it to the desired qualities. Ventilation systems are being designed depending on these physical rules. These are active systems: Fans, air conditioning installations and Passive systems: Natural air ventilation, natural wind, windows, doors, vents, and chimneys.

3.BIOMIMETIC APPROACH IN ARCHITECTURAL DESIGN

Biomimetic is a concept first used by the American engineer Otto Schmidt in 1950. This word, which is derived from the combination of the words bios (life) and mimesis (imitation) in Greek. It is the design principle that seeks sustainable solutions to the problems of humanity by examining the principals and strategies that nature has tested for centuries through natural formations [10].

The principles of natural formations are used in architectural design for structural systems, building form, kinetic flexible buildings, and building physics Figure 1 [11].

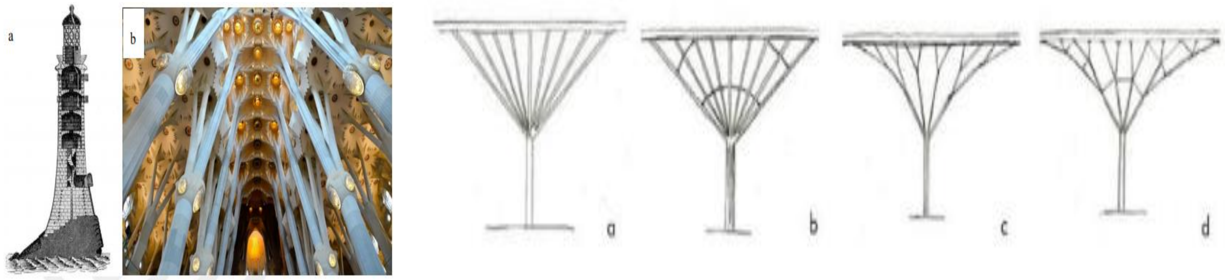


Figure 1. *The use of the biomimetic approach in structural systems (http://www.webcitation.org/quer).*

In this study, the “Termite Ant Nest” air ventilation principle was investigated as a passive ventilation method in architectural design. The rise of the heated air in the natural nest structure, its discharge from the upper chimneys, and the intake of fresh air from the entrances on the ground provide data for the natural ventilation system in the buildings Figure 2[11].

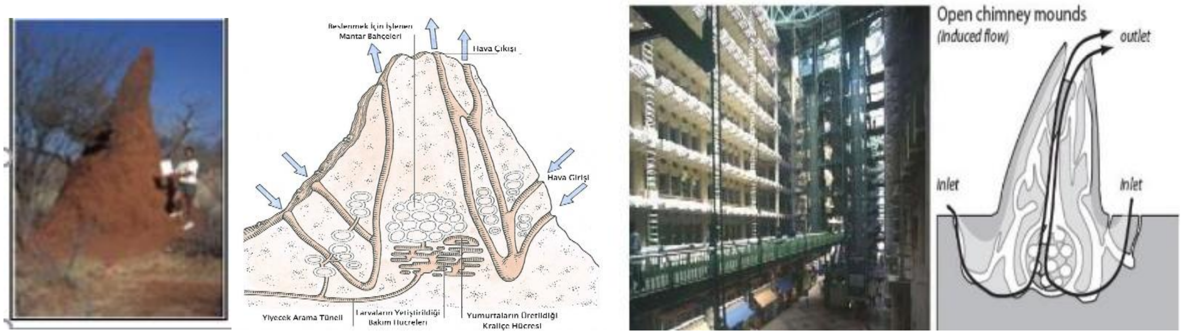


Figure 2. *Termite anthill ventilation system (Internet: Eastgate; URL: http://www.webcitation.org/query).*

4. USE OF BIOMIMETIC ARCHITECTURAL DESIGN APPROACH IN PASSIVE NATURAL VENTILATION IN EDUCATIONAL BUILDINGS

The architecture department of Gazi University was examined for passive natural ventilation, inspired by the termite ant nest in a biomimetic context. The building typology of the Faculty of Architecture is rectangular prism. Classrooms, and lecture halls are placed on two long directions, recess areas, and wet areas in the middle part of the plan. (Figure 3). Termite ants’ natural ventilation principle was used on the 3rd. studio’s floor. Fresh air inlet vents were placed on the building’s exterior surfaces and chimneys for polluted air outlet were placed in recess corridors to obtain a zero energy passive ventilation system. Figures 4 and 5 [7].

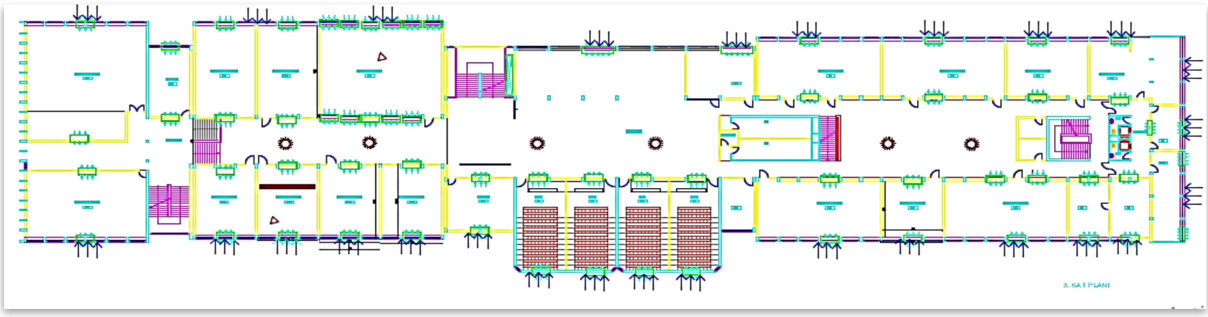


Figure 3. *Plan layout of architectural floor chimneys and valves drawn in AutoCAD software (Tohidi, 2020).*

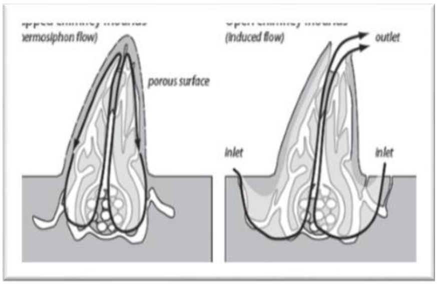


***Figure 4.** Anthill ventilation system (Internet: Eastgate; URL: http://www.webcitation.org/query).*

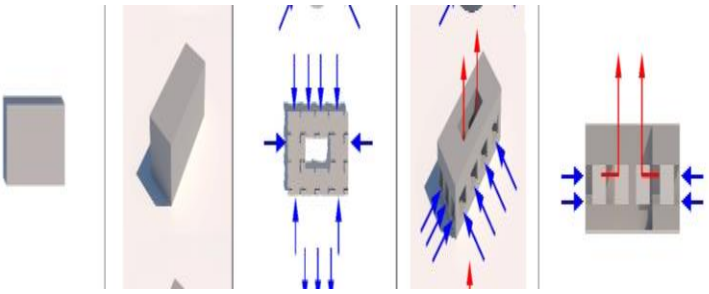


***Figure 5.** Gazi University architecture department floor, natural ventilation design principle, drawn in 3Ds MAX software (Tohidi, 2020).*

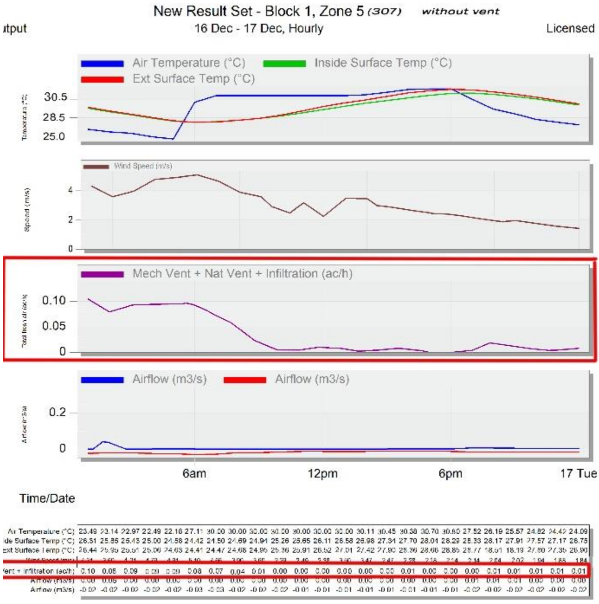
Design studio halls 307 and 304B were chosen as study areas on the architecture department floor of the faculty. This design was modeled in a computer environment and its performance was analyzed in the "Design-Builder Energy plus 6.1.8.021" software [12].

4.1. Local Mean Age of Air (LMA) and Space Average Air Use Analysis in Studio 307

307 studio hall is 195 m2 in total, with a capacity of 100 students, 13 m deep, and 15 m wide. The ceiling height is 3.60 m, and the space volume is 702 m3. Clean air usage and users' needs in 307 spaces (Figures 6 and 7) were analyzed in two stages. In the first stage, the fresh air of the classroom with 100 students was observed when the students came to the first lesson in the morning windows were closed. The air entering the space under the window level and the door was ignored in the software input as it is a very small amount (0.025 m3). There is no leakage as there is the gasket on the window sashes.

***Figures. 6 and 7.** Studio 307 (Tohidi, 2020).*

The amount of fresh air in the classroom at 8.00 a.m. is 702 m3. According to TS 12281 (1997), each student uses a minimum of 7 m3 of fresh air per hour. Since it has a capacity of 100 students, 700 m3 of air is consumed per hour [13]. There is no fresh air in the studio in the second hour, indicating that the EnergyPlus calculation ends at 9.00 a.m. Figures 8 and 9.



Air Temperature (°C)	23.49	23.14	22.97	22.49	22.16	27.11	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.11	30.45	30.38	30.70	30.60	27.52	26.19	25.57	24.82	24.42	24.09
ide Surface Temp (°C)	26.31	25.85	25.43	25.00	24.58	24.42	24.50	24.69	24.94	25.26	25.65	26.11	26.58	26.98	27.34	27.70	28.01	28.29	28.33	28.17	27.91	27.57	27.17	26.75
Ext Surface Temp (°C)	26.44	25.95	25.51	25.06	24.63	24.41	24.47	24.68	24.95	25.36	25.91	26.52	27.01	27.42	27.90	28.36	28.66	28.85	28.77	18.51	18.19	27.80	27.35	26.90
Wind Speed (m/s)	[illegible]	3.66	4.31	4.70	4.91	5.10	4.66	3.96	3.60	2.79	2.49	2.38	3.50	3.47	2.47	2.28	2.16	2.14	2.14	2.04	2.02	1.94	1.88	1.84
ent + Infiltration (ac/h)	0.10	0.06	0.09	0.09	0.09	0.08	0.07	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Airflow (m3/s)	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Airflow (m3/s)	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02

Figure 8. *307 studio air exchange in EnergyPlus software; diagram was calculated in the EnergyPlus software before the vents were applied (Tohidi, S., 2020)*

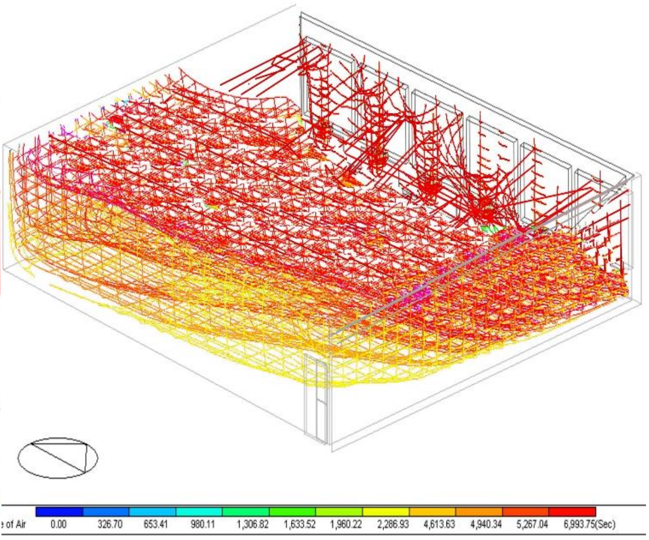


Figure 9. *At the beginning of the second lesson in the morning at studio 307, the exhaustion of the fresh air amount was simulated in the design-builder software (Tohidi, 2020)*

4.2. Analysis of LMA (Local Mean Age of Air) and Space Average Air Use in Studio 307 with The Recommended Passive Ventilation Method:

Three points are important in the proposed passive ventilation system.

1. Ensuring the flow of fresh air as much as the amount of air used indoors from the outside wall, sufficient air inlet vents;
2. While providing fresh airflow, the wind effect (indoor air circulation speed) should not be felt regarding the user’s comfort, and airflow must move at a slow flow rate.
3. The fresh air should get warmer by passing through the heating radiator slices while conveying it from outside during the education period in the winter months.

Design Builder software does not recommend a specific window or air inlet (vent) size. Instead, it calculates and simulates the amount of fresh air according to the dimensions proposed by the designer in architectural design. The software calculates airflow factors such as the geographical location of the building and the prevailing wind direction/speed. In this study, various sizes of air inlet ventils and chimney sizes were tested. Simulations and calculations, assuming the winter period, vent and chimney dimensions suitable for the air usage purpose were obtained. In this study, 6 pieces of 30 cm × 15 cm air inlet vent with collapsible fins (blades) or slider and filter, and the same number and size of air passage gaps are placed on the corridor wall (Figure 10). In the middle corridor area, 144 cm diameter air outlet chimneys are placed up to the roof (Figures 11 and 12.)

Figure 10. 15 cm x 30 cm air inlet vent with retractable blades (https://hizhavalandirma.com/)

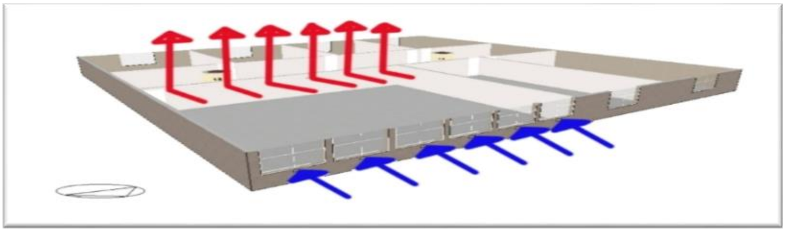


Figure 11. 307 studio Architecture floor without applying cross-section of the air outlet /chimneys first drawn in th Energy Plus software (Tohidi,2020).

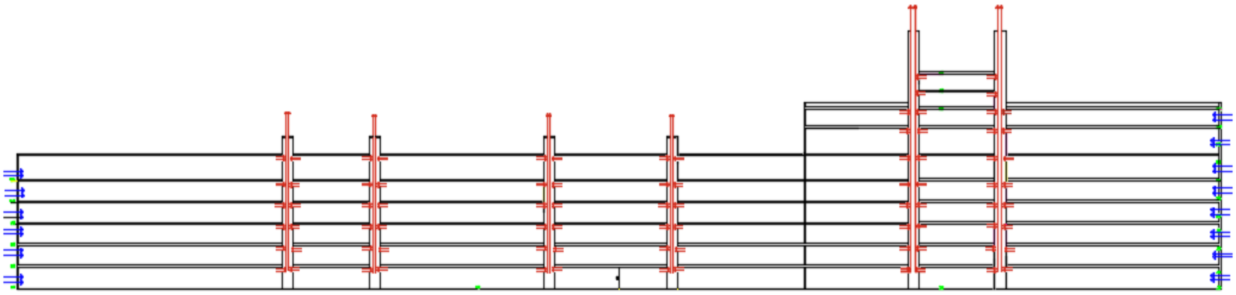


***Figure 12**. The cross-section of the architecture floor air outlet chimneys was drawn in Autocad software (Tohidi, 2020).*

According to the Computational Fluid Dynamics (CFD) analysis at the first stage, the air in the volume (Age of Air) is completely cleaned in 2800 seconds (46.6 minutes) in the natural ventilation system at the specified dimensions in Figures 13 and 14. When this calculation is made, it turns out to be 15.06 m3/minute. This amount is over 11.66 m3/minute consumed by students per minute in the classroom. With this design, fresh air is provided above the users' needs with the passive method.

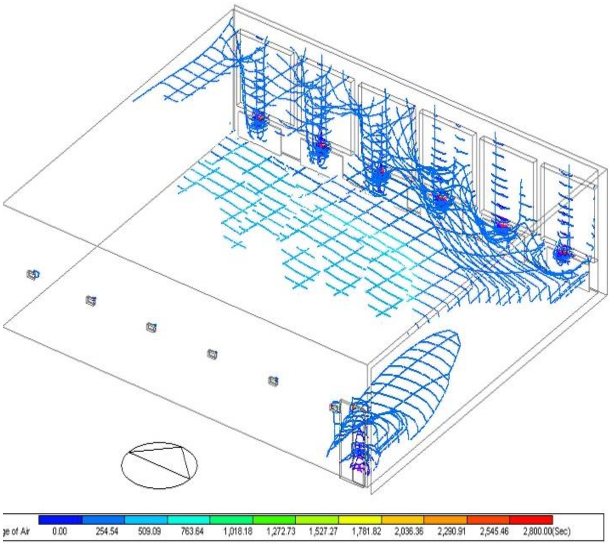


***Figure13.** it takes 2800 s (46.6 min) to completely clean the indoor air (15.06 m3/min) when the vents are open; simulated in DesignBuilder software (Tohidi, 2020).*

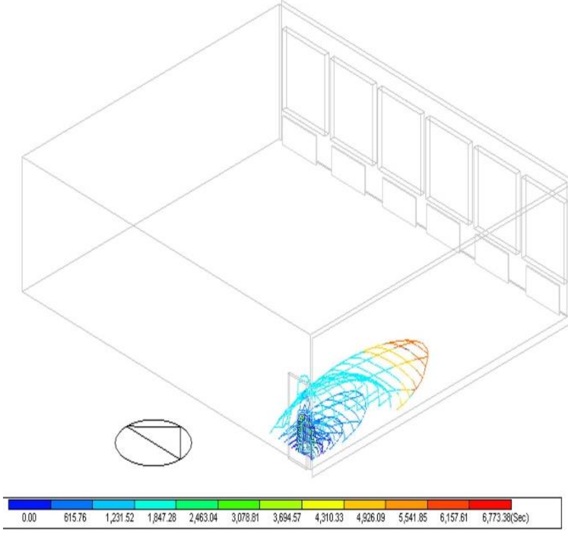


***Figure 14.** The amount of air entering from below the door when the vents are closed is 0,0025 m3; simulated in DesignBuilder software (Tohidi, 2020).*

Another factor in indoor air quality is the indoor air renewal flow rate such that people do not feel the wind. The velocity of the air movements (m/s) is measured with an anemometer [14].

The second criterion in the 307 studio is that the airflow does not create a wind effect, and the comfort level is kept constant for the user's comfort. Airflow velocity (m/s) in non-ventilated systems was very low (between 0.02 m/sec and 0.07m/s), causing no air change Figure 15. In both mechanical and natural ventilation systems, the airflow rate (m/s) is comfortable between 0.09 m/s and 0.13 m/s. According to TS 12281 (1997). The indoor' airflow rate should be in the range of 8 m/min to 10 m/min in winter and 13 m/min to 27 m/min in summer. However, air velocity less than 0.06 m/sec is not perceived such that it creates a feeling of airlessness. Speeds between 0.25 m/s and 0.50 m/s are pleasant. Finally, air velocity of 1.5 m/s and higher creates an uncomfortably fast airflow [11], [15].
In the 307 studio, the airflow velocity is only 0.90 m/s at the inner vents and provides the desired comfort quality Figure 16.

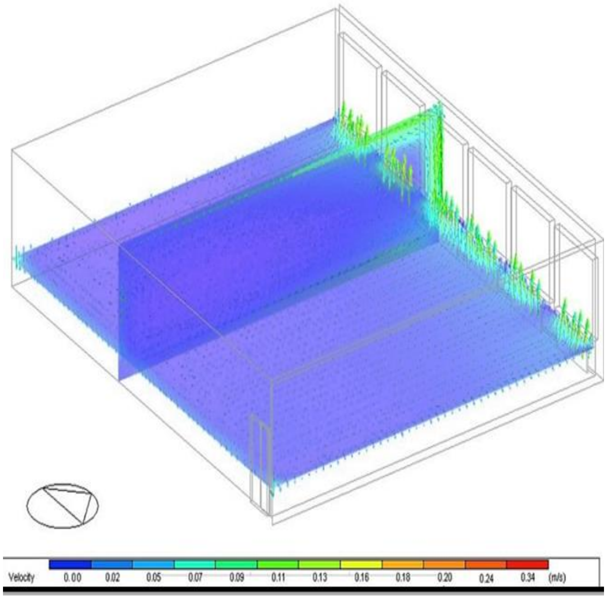


Figure 15. *The indoor airflow simulation was simulated in DesignBuilder software in case there were no ventilates in Studio 307 (Tohidi, 2020).*

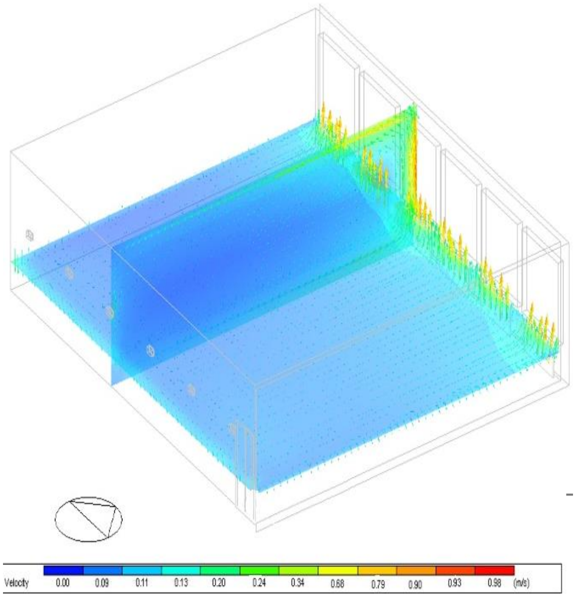


Figure 16. *indoor airflow simulation was simulated in DesignBuilder software with the ventilates open in 307Studio (Tohidi, 2020).*

The third important criterion in the proposal of a biomimetic passive ventilation system is that the cold air coming from outside must not reduce the indoor temperature during the winter months. The environmental classroom temperature should be kept at 20-25℃ in winter and 23-26℃ in summer [15]. In the proposed passive ventilation system, the air taken from outside passes between the heater radiators placed in front of the vents and gets heated and taken to indoors. In the Design-Builder EnergyPlus program [12], the water temperature inside the radiators in the 307 studio is considered 60℃. In this case, the room temperature is 27.40℃ in front of the radiator, 24℃ in the whole place, and 22.89℃ only in front of the door. In the absence of a passive ventilation system, these values are 30.63℃ in front of the radiator, 25.34℃ in the middle of the room, and 22.60℃ in one-third of the remaining space. These results show that the heat is not distributed homogeneously in the ventless system. The heat distribution is more homogeneous to the air velocity in the ventilated system Figures 17 and Figures 18.

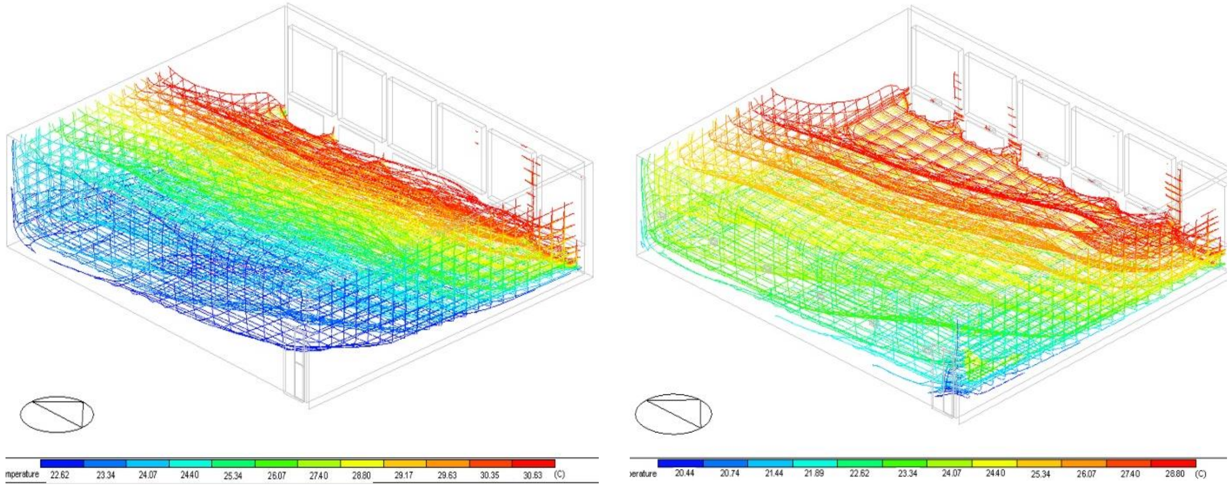
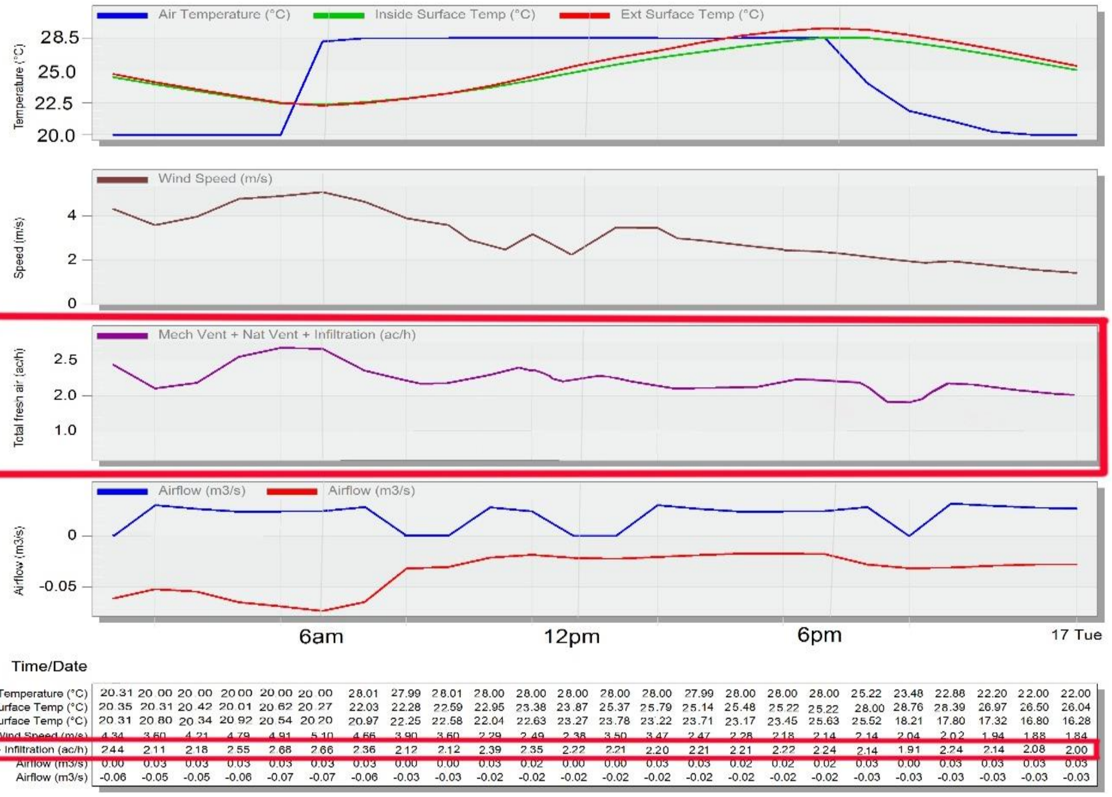


Figure 17. *Indoor heat distributions in studio 307 with and without ventilates are placed in simulated in DesignBuilder software (Tohidi, 2020).*



Time/Date																								
Air Temperature (°C)	20.31	20.00	20.00	20.00	20.00	20.00	28.01	27.99	28.01	28.00	28.00	28.00	28.00	28.00	27.99	28.00	28.00	28.00	25.22	23.48	22.88	22.20	22.00	22.00
Inside Surface Temp (°C)	20.35	20.31	20.42	20.01	20.62	20.27	22.03	22.28	22.59	22.95	23.38	23.87	25.37	25.79	25.14	25.48	25.22	25.22	28.00	28.76	28.39	26.97	26.50	26.04
Ext Surface Temp (°C)	20.31	20.80	20.34	20.92	20.54	20.20	20.97	22.25	22.58	22.04	22.63	23.27	23.78	23.22	23.71	23.17	23.45	25.63	25.52	18.21	17.80	17.32	16.80	16.28
Wind Speed (m/s)	4.34	3.60	4.21	4.79	4.91	5.10	4.66	3.90	3.60	2.29	2.49	2.38	3.50	3.47	2.47	2.28	2.18	2.14	2.14	2.04	2.02	1.94	1.88	1.84
Vent + Nat Vent + Infiltration (ac/h)	2.44	2.11	2.18	2.55	2.68	2.66	2.36	2.12	2.12	2.39	2.35	2.22	2.21	2.20	2.21	2.21	2.22	2.24	2.14	1.91	2.24	2.14	2.08	2.00
Airflow (m3/s)	0.00	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.00	0.03	0.02	0.00	0.00	0.03	0.03	0.02	0.02	0.02	0.03	0.00	0.03	0.03	0.03	0.03
Airflow (m3/s)	-0.06	-0.05	-0.05	-0.06	-0.07	-0.07	-0.06	-0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03

Figure 18. *Diagram of air renewal, airflow, and indoor air temperature after vents applied in the 307 studio (Calculated in EnergyPlus software by Tohidi (2020)).*

4.3. LMA (Local Mean Age of Air) Space Average Air Use Analysis at Studio 304B

The design studio hall 304B Figures 19 and 20 on the architecture department floor of the selected faculty was chosen as the second study case area. This place has a capacity of 30 students and is 9.9 m deep and 7.50 m wide, with a total area of 74.25 m2. The ceiling height is 3.60 m., and the space volume is 267.3 m3.

Figures 19 and 20. *304B interior view and recess corridor (Tohidi, 2020).*

The fresh air use of users in space 304B was analyzed in two stages. In the first stage, air variations were monitored for the first lesson classes with 30 students while closing the windows. At this stage, which was modeled in the Design-Builder software, the reduction in air cleanliness and its duration were calculated through the simulation. Also, when the windows and door are closed, the amount of air entering the room under the window sashes, and the door is ignored because it is very small. In the classroom, the amount of fresh air in the studio is 267.3 m3 at the morning entrance time of the student. Each student uses 7 m3 of air per hour. Since hall 304B has a capacity of 30 students, it needs 7 m3 of fresh air per student, indicating that it consumes 210 m3 of air per hour Figure 21. The simulation shows that the amount of fresh air decreases by 3.5 m3 per minute and remains at 57.3 m3 one hour after the students' entrance Figure 22. Using 3.5 m3 of air per minute, there is no fresh air in the studio after 16 min of the second lesson hour Figure 23. The diagram shows that the air exchange stops at 10 o'clock in the Energy Plus environment Figure 24.

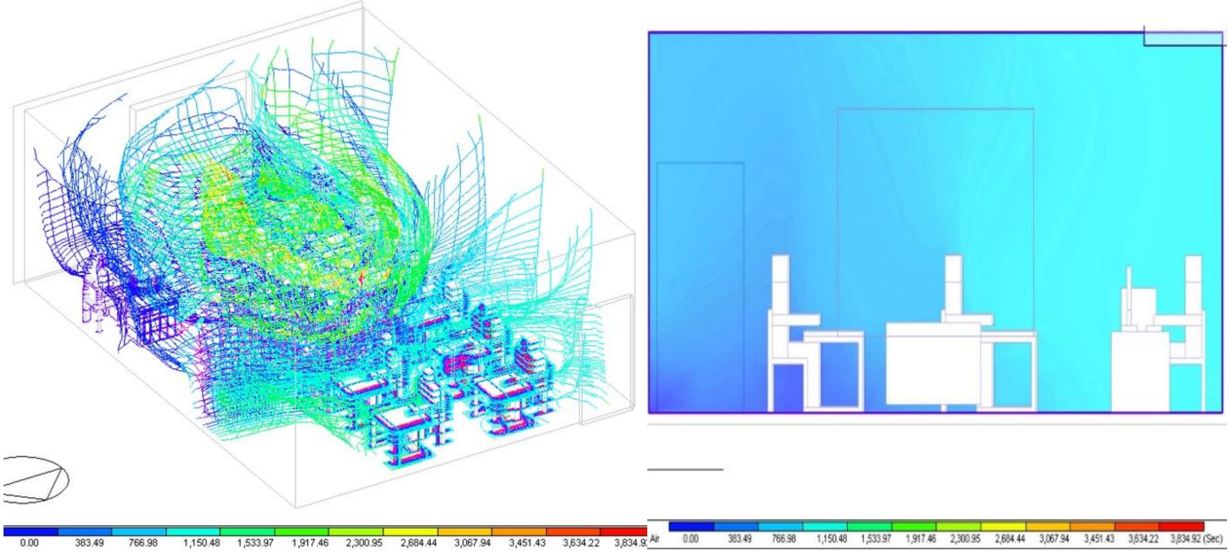


Figure 21. *The amount of fresh air in the classroom 304B before the student arrives in the morning; is simulated in DesignBuilder software (Tohidi, 2020).*

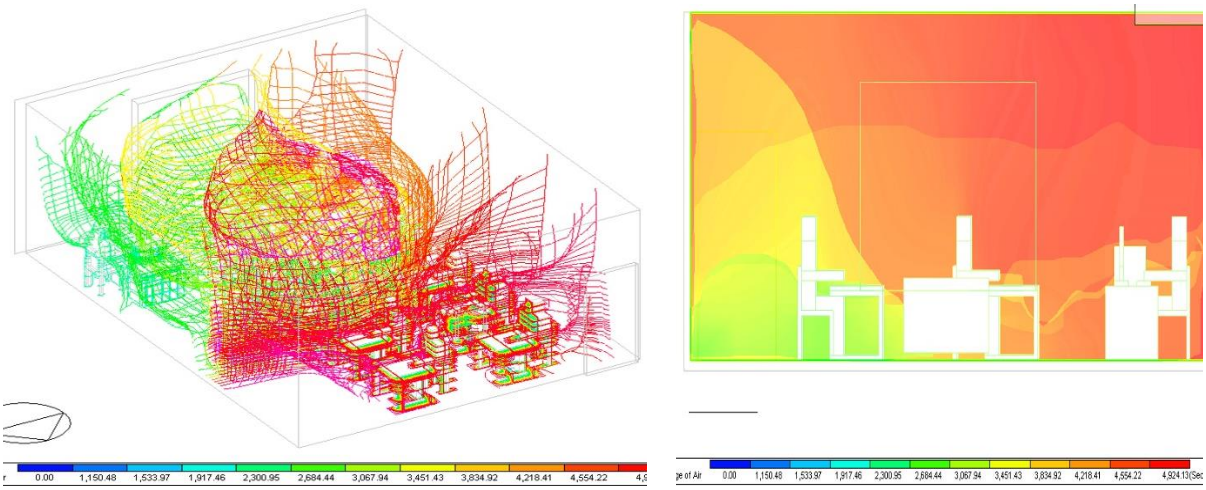


Figure 22. *Simulation of air usage amount after 60 min with 30 students in classroom 304B; simulated in DesignBuilder software (Tohidi, 2020).*

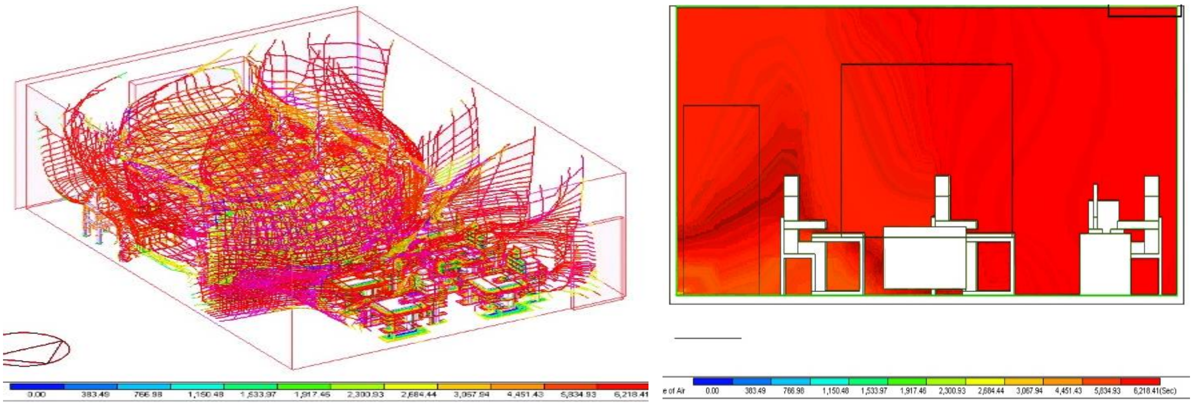
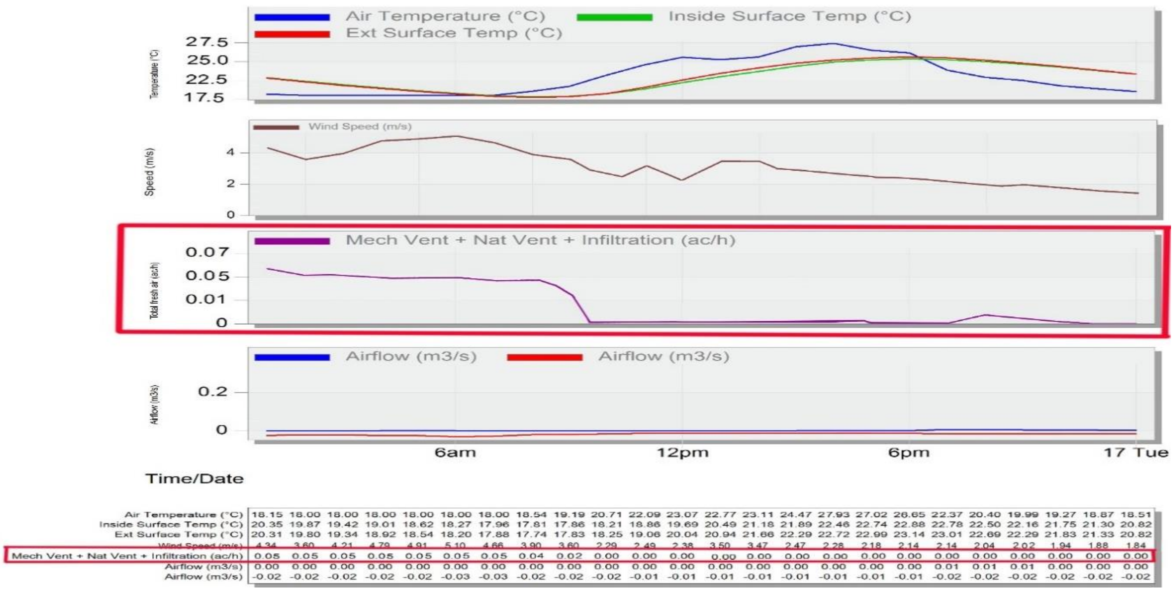


Figure 23. *Simulation of the complete exhaustion of air volume after 76 min with 30 students in classroom 304B, simulated in DesignBuilder software (Tohidi, 2020).*



Air Temperature (°C)	18.15	18.00	18.00	18.00	18.00	18.00	18.00	18.54	19.19	20.71	22.09	23.07	22.77	23.11	24.47	27.93	27.02	26.65	22.37	20.40	19.99	19.27	18.87	18.51
Inside Surface Temp (°C)	20.35	19.87	19.42	19.01	18.62	18.27	17.96	17.81	17.86	18.21	18.86	19.69	20.49	21.18	21.89	22.46	22.74	22.88	22.78	22.50	22.16	21.75	21.30	20.82
Ext Surface Temp (°C)	20.31	19.80	19.34	18.92	18.54	18.20	17.88	17.74	17.83	18.25	19.06	20.04	20.94	21.66	22.29	22.72	22.99	23.14	23.01	22.69	22.29	21.83	21.33	20.82
Wind Speed (m/s)	4.34	3.60	4.21	4.79	4.91	5.10	4.66	3.90	3.60	2.29	2.49	2.38	3.50	3.47	2.47	2.28	2.18	2.14	2.14	2.04	2.02	1.94	1.88	1.84
Mech Vent + Nat Vent + Infiltration (ac/h)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Airflow (m3/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
Airflow (m3/s)	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02

Figure 24. *304B air exchange diagram in energy plus software, calculated in Design builder software (Tohidi, S.,2020).*

4.4. Analysis of LMA and Space Average Air Use in Studio 304B with The Recommended Passive Ventilation Method:

As stated above, with 30 students, the clean air in the space volume dimensions decreases by 3.5 per minute and ends in 76 min. Vent and chimney dimensions suitable for the purpose have been reached due to simulations and calculations, assuming the winter period. A 30 cm × 15 cm air inlet ventile with 3 collapsible fins (blades) or slider and filter and the same number and size of air passage gaps are placed on the corridor wall in Figures 25 and 26.

Figure 25. *15 cm x 30 cm air inlet grille with collapsible blades (https://hizhavalandirma.com/)*

Figure 26. *The layout of the air inlet and outlet valves in Classroom 304 is drawn in DesignBuilder & 3Ds MAX software (Tohidi, 2020).*

Regarding the specified vents, the CFD analysis results show that the air in the volume (LMA) is fully renewed in 3,593 s (59.88 min). When this calculation is made as m3/min, it comes out as 3.50 m3/min. This amount equals 3.50 m3/min consumed by students per minute in the classroom Figures 27 and 28.

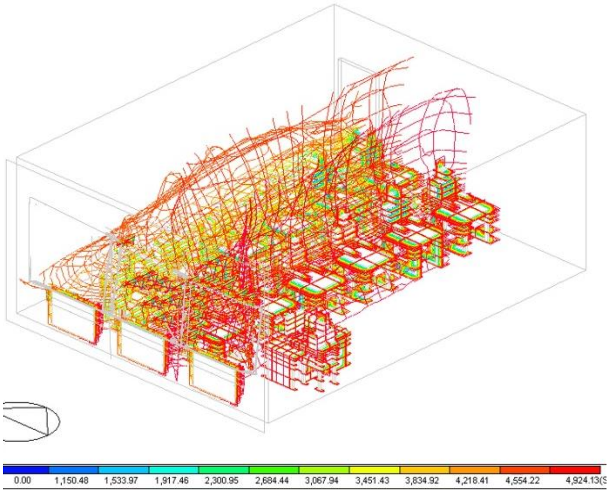


Figure 27. *In-studio 304B, with the vents closed, it takes 4560 s (76 min) to finish the fresh air; simulated in DesignBuilder software (Tohidi, 2020).*

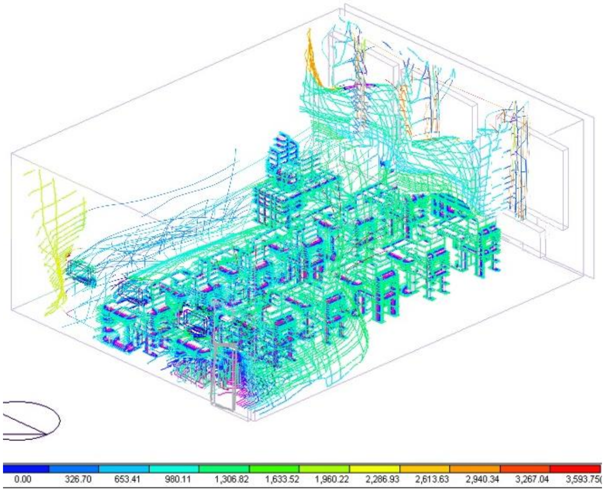


Figure 28. *When the vents are open in studio 304B, it takes 3.50 m3/min and 3,593 s (59.88 min) to clean the indoor air completely; simulated in the DesignBuilder software (Tohidi, 2020).*

In addition to providing the required amount of air in the passive ventilation system made in the 304B studio, the second criterion is that the airflow does not create a wind effect, and the comfort level is kept constant for the users. Before the vents are applied, the airflow velocity is between 0.02 m/s and 0.05 m/s Figure 29. When the vents are open, the airflow rate is 0.13 m/s in front of the vents, and its speed decreases indoors until providing the desired comfort quality Figure 30.

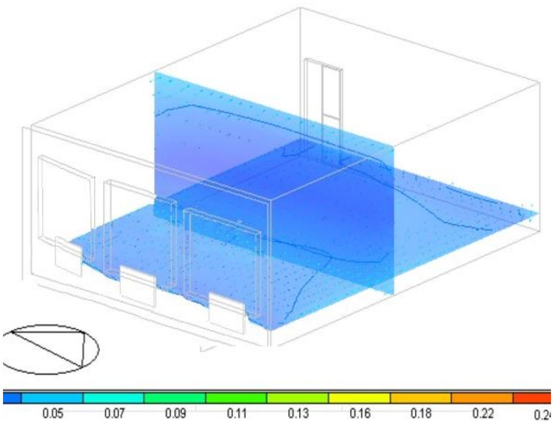


Figure 29. *The indoor airflow (velocity) simulation in DesignBuilder software (Tohidi, 2020) in Studio 304B without the valves.*

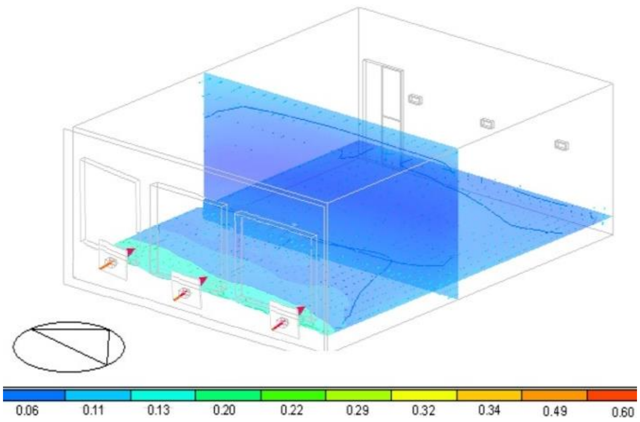


Figure 30. *Indoor airflow (velocity) simulation in DesignBuilder software while the valves were open in Studio 304B (Tohidi, 2020).*

The third important criterion in the proposal of a biomimetic passive ventilation system is that the cold air from outside during the winter does not reduce the indoor temperature. It is assumed that the water temperature at the radiators is 60℃ in the 304B studio. In the absence of a passive ventilation system, it is 27.80℃ in front of the radiator, 22.62℃ in the middle of the room, and 18.25℃ in the volume of one-third of the remaining space Figure 31. Also, in the case of vents, the room temperature is 25.80℃ in front of the radiator, 23.34℃ in the whole space, and 20.44℃ only in front of the door. These data show that the heat is not distributed homogeneously in the ventless system and that the heat distribution is more homogeneous thanks to the air velocity in the vented system Figures 32 and 33.

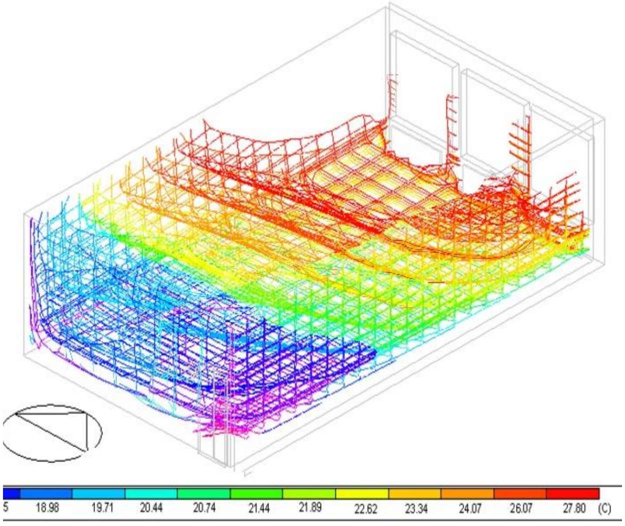


Figure 31*. Interior in Studio 304B Without vents; Heat Distribution in DesignBuilder software (Tohidi, 2020).*

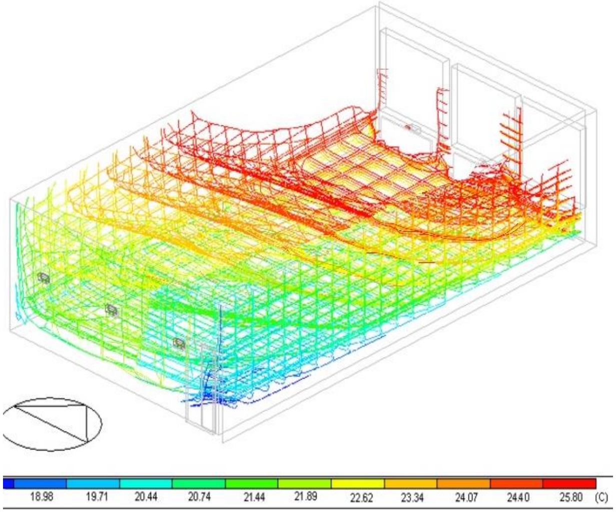
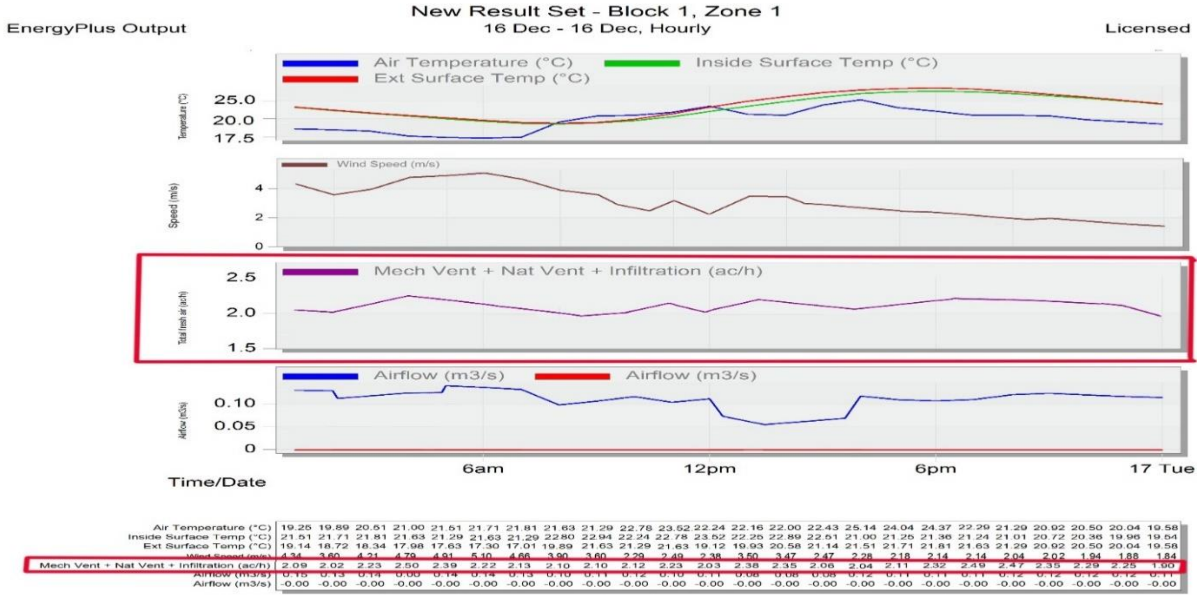


Figure 32. *Interior Space by open vents Situations in Studio 304B; Heat Distribution simulated in DesignBuilder software (Tohidi, 2020).*



Air Temperature (°C)	19.25	19.89	20.51	21.00	21.51	21.71	21.81	21.63	21.29	22.78	23.52	22.24	22.16	22.00	22.43	25.14	24.04	24.37	22.29	21.29	20.92	20.50	20.04	19.58
Inside Surface Temp (°C)	21.51	21.71	21.81	21.63	21.29	21.63	21.29	22.80	22.94	22.24	22.78	23.52	22.25	22.89	22.51	21.00	21.25	21.36	21.24	21.01	20.72	20.36	19.96	19.54
Ext Surface Temp (°C)	19.14	18.72	18.34	17.98	17.63	17.30	17.01	19.89	21.63	21.29	21.63	19.12	19.93	20.58	21.14	21.51	21.71	21.81	21.63	21.29	20.92	20.50	20.04	19.58
Wind Speed (m/s)	4.34	3.60	4.21	4.79	4.91	5.10	4.66	3.90	3.60	2.29	2.49	2.38	3.50	3.47	2.47	2.28	2.18	2.14	2.14	2.04	2.02	1.94	1.88	1.84
Mech Vent + Nat Vent + Infiltration (ac/h)	2.09	2.02	2.23	2.50	2.39	2.22	2.13	2.10	2.10	2.12	2.23	2.03	2.38	2.35	2.06	2.04	2.11	2.32	2.49	2.47	2.35	2.29	2.25	1.90
Airflow (m3/s)	0.15	0.13	0.14	0.00	0.14	0.14	0.13	0.10	0.11	0.12	0.10	0.11	0.08	0.08	0.08	0.12	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.11
Airflow (m3/s)	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

Figure 33. *Air Regeneration, Air Flow, and Indoor Air Temperature Diagram after Ventiles Applied in Studio 304B; simulated in DesignBuilder software (Tohidi, 2020).*

5. CHIMNEY DESIGN PRINCIPLES IN PASSIVE VENTILATION

Chimneys are divided into Fire chimneys, Ventilation chimneys, Garbage chimneys, and Installation chimneys (plumbing, power etc.) according to their intended use. Natural, non-mechanical chimneys were used in the proposed design.

In the zero-energy passive ventilation design where calculations and simulations are made in two studios in the architecture department of the Gazi University. The quantity of students and the size of the lecture hall is the basic input parameters of the proposal. Depending on these parameters, the external wall air vents and the polluted air outlet between the corridor and the studio were measured. This suggestion can be implemented by changing the space/person parameters in other departments of the faculty on different storeys. This parameters may change in different public buildings such as offices, administration, and education buildings.

Another important design problem in this system is the removal of the polluted air used indoors from the building. Chimney design comes into question here. In the chimney design. It is not desired to discharge the air with electromechanical installations. Natural chimney system (zero energy) is selected. Chimneys have been created in the corridors and student recess areas located between the classrooms. Polluted air is taken in through the vents on these chimneys and thrown out from the roof.

5.1.Ventilation Chimneys

They are made to expel the used, moist and smelly air. Ventilation chimneys are generally used in toilets and bathrooms. Its minimum dimensions should be 45*45 cm [13] according to Turkish Standards.
In the architectural design, naturally ventilated chimneys and galleries inside the building are used as indoor natural ventilation.

5.2. Architecture Faculty Education Studios Chimney Design

The main principle of the chimney design is that the high-pressure air heated by the breath in the interior rises at a lower temperature. In other words, there is fluid dynamic flow (air transfer) from high pressure to low pressure. Important parameters in chimney design and dimensioning can be listed as follows:

-The annual average wind speed of the geographical point where the building is located (m/s).
-Pressure difference between indoor and outdoor air (temperature difference)
-Chimney material, inside surface (fluid material friction)
-Chimney height (pressure difference increases as the chimney height rises)

Since the chimney is an air duct, the air duct and chimney calculation can be made according to the chimney dimensions, air flow, air movement in the space, and the temperature distribution of the space.

5.3. Natural Ventilation Chimney Calculation of Classrooms

Chimneys are the last piece of equipment in ventilation and air conditioning systems. The purpose of the chimneys is to remove the polluted air from the environment by the architectural design, to convey the fresh air inside, to give the necessary airflow, to spread the air in the space, not create disturbing air currents, and not to cause discomfort or noise due to the airflow in the space. While making chimney selections in natural ventilation systems,

– Air exchange amount (equalizing the amount of clean air required for users with the polluted air coming out of the chimney)

– Chimney type selection should be made considering the architectural features.

Since the number of students is accepted as 30 for class 304B, 3.5 m3 of air per minute and 0.05 m3 of air per second are used. The 307 class has a capacity of 100 students and uses 11.66 m3 of air per minute and 0.19 m3 of air per second. A total fresh air amount of 0.05+0.19=0.24 m3/s per second for both classrooms was found in the clean air vent simulation. The chimney to be designed for the polluted air outlet must be sized to throw this amount from the roof.

Ventilation chimney cross-section size [16] :

V= A x W

V= Volume, m3/hour (the amount of air expelled in an hour) which in this calculation is equal to **0.24 m3/s**

A= Area,m2 (chimney interior cross-sectional area) which in this calculation is unknown, we need to find

W= Wind speed, m/second (varies according to the different geographic areas) Ankara's wind speed is equal to **1.8 m/s**

In this formula, the amount of air that needs to be expelled from the interior and the various chimney section sizes are changed, and there is sufficient chimney section size. It should be obtained equal to or greater than the amount of air used indoors.

The total amount of air required for both studios of the architecture department is 0.24m3 per second, and the average wind speed for Ankara during the months of the education period (October - June) (9-6.8 km/h) gives the value between 2.5 m/s and 1.8 m/s. It is necessary to take the lowest wind speed that provides the most useful cross-section for the chimney draft. As the wind speed increases, the chimney draft will increase

$$\mathbf{V = A \ x \ W \Rightarrow 0.24m3/s = A \ x \ 1.8m/s \Longrightarrow 0.24\ m\ {}^{3}/_{s}\ x\ 1.8A\ \ m\ /\ s \Rightarrow A = \frac{0.24m^{3}/_{s}}{1.8m/_{s}} = 0.13m^{2}}$$

chimney size for two classrooms

This chimney size, which is sufficient for two studios on the architectural education floor, will double on the upper floors and triple on the fifth floor if the number of students is considered the same Figures 34,35. Another architectural solution is to leave gallery spaces between the floors that will serve as chimneys Figure 36.

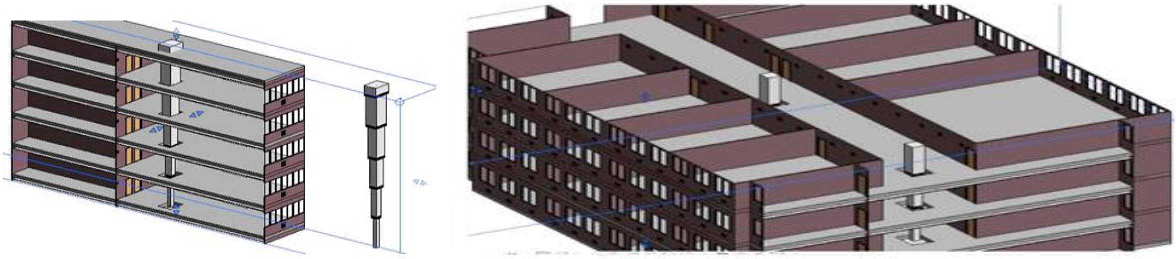


Figure 34. *The increase in the cross-section of the dirty air outlet chimneys on the floors and the settlement points inside the building were drawn in Revit 2016 software (Tohidi, 2022).*

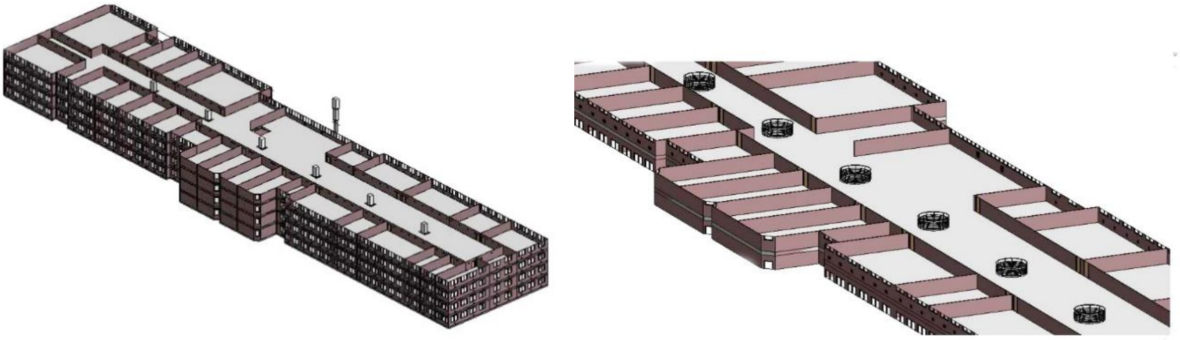


Figure 35. *Layout points of air outlet chimneys on the education block floor were drawn in Revit 2016 software (Tohidi, 2022).*

Figure 36. *Dirty air exit gallery spaces between floors were drawn in Revit 2016 software (Tohidi, 2022).*

6. RESULTS

Indoor air exchange and the renewal of fresh air in a building are important for the user's health. This issue has great importance, especially in offices, educational buildings, health buildings and cultural buildings with auditorium halls that used by intense users.

This subject is the study area of building biology in architectural sciences. According to the WHO reports, there are 4.3 million patients in buildings whose indoor air is not renewed annually. According to field studies of organizations working on indoor air quality, heart, lung, and brain functions are seen in occupants of buildings with low indoor air quality.

In this study, a natural ventilation system with "zero energy" use and passive methods was proposed in the Faculty of Architecture of Gazi University. Sustainable and carbon emission-free natural ventilation is provided with a completely passive method without using electrical energy and operational, maintenance cost. The proposed architectural design system was implemented by impression of the "termite ant nest" ventilation system in nature.

On the education floor of the architecture department, in the 307 and 304B education studios with a capacity of 100 students, the model proposal was realized by placing open/closed vents on the outer walls and dirty air outlet chimneys in the middle recess areas. The ventilation simulation and calculations of the proposed model were made in the "Design-Builder EnergyPlus" software. According to the results, a sufficient amount of fresh air is provided all day in both studios without losing heat in the winter months.

Chimneys have been created in the corridors and student recess areas located between the classrooms. Polluted air is taken in through the folding louvre vents on these chimneys and thrown out from the roof.

The chimney type selection should be made by considering the amount of air exchange (the amount of clean air required for users is equalized with the polluted air coming out of the chimney) and architectural features when choosing the chimney type in natural ventilation systems. The ventilation chimney cross-section is calculated by the fluidity calculator V = A x W formula, where V = volume m3/hour, A = area m2, and W wind m/s.

While evaluating the proposed model and results, the applicability of the system in other intense user building types was realized. This zero energy natural ventilation design proposal can be used in many other building types such as offices, educational buildings, health buildings, libraries, cultural buildings, permorming art halls and auditoriums which have intense users in it. Another advantage of a zero-energy, passive natural ventilation system is its low initial investment cost and lack of operating, energy costs than electromechanical systems.

REFERENCES

[1] WHO (World Health Organization), Carbon Monoxide”, Air Quality Guidelines for Europe, European Series 23, WHO Regional Publications, Copenhagen.1987, Denmark.

[2] Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017. (GBD 2017) Results. Seattle, USA: Institute for Health Metrics and Evaluation (IHME), 2017, USA.

[3] Paula Baker- Robert Laporte, EcoNest: Create Sustainable Sanctuaries of Clay, Straw, and Timber, publish Gibbs Smith,).page 135,2005, Hong Kong.

[4] Fanger, P., O. Thermal Comfort: Analysis And Applications İn Environmental Engineering. Publisher Danish Technical Press. Page 244,1970, USA.

[5] BALANLI, A., "Building Elements 2-Joinery", YTU Department of Architecture, Building Elements and Materials, Unpublished Lecture Notes. 2007. YTU, Istanbul.

[6] Ozgenalp, A., Ventilation and Filtration Systems in Shelters, Journal of Installation Engineering Issue: 91, p. 56-62. 2006.

[7] ASHRAE Fundamentals “Air Flow Around Buildings”, Translated by O. GENCELI, Association of Installation Engineers Publication No: 4. , 2010, USA.

[8] Cinemre, H., Goldenhar Syndrome Goldenhar Syndrome Asthma - Cardiological Disease Profile and Air Quality Evaluation, (Sakarya University Faculty of Medicine, Department of Obstetrics and Gynecology, Sakarya, Turkey), Sakarya Medical Journal, Volume: 7, 2017, Sakarya, Turkey.

[9] Santamouris, M., Natural Ventilation in Buildings, Chapter 6.1.4.1, James & James (Science Publishers), 1998, London.

[10] Benyus, J. M. Biomimicry: Innovation Inspired by Nature, William Morrow and Company Inc., New York. Book,320 pages, 1997 San Francisco, USA.

[11] ZORER, G. “Principles of Thermal Design in Buildings”, YTU Faculty of Architecture Publications, University Publication No: 264, Faculty Publication No: MF-MIM 92.045, Istanbul, 1992.

[12] http://www.DesignBuilder Software Ltd - Tutorials, tutorials design-builder, 2020, USA.

[13] Turkish Standard Ts Cr 1752, Ics 91.140.30 “Ventilation for Buildings - Design Rules for Indoor Environments” (11) Taner. 1997, Turkey.

[14] Y.Kwok1aA. D., Neumann, W., Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 161, Issue 1, January 15, Pages 31-48, Cambridge, MA 02139, 2000, USA.

[15] http://www.cedbik.org, Accessed: Subject: Environmentally Friendly Green Buildings Association Studies, 10.08.2018.

[16] Yunus A. Çengel. and Cimbala, John M., “Fluid Mechanics: Fundamentals and Applications”, PDF - 956 pages, the University of California. Publisher McGraw-Hill Education, 2006. (ISBN 0071257640, 978007125764), 2006, USA.